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Decreasing time-waste in production through digitalization

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology.

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Jo vuosikymmenien ajan rakennusalan tuottavuus on ollut alhainen johtuen tehottomuudesta. Tuotannossa lean teorian avulla löydetään hukan lähteet ja korvataan ei-arvoa-tuottavat toiminnat arvoa-tuottavilla aktiviteeteillä. Kuitenkin rakennusalan haasteina ovat rakentamisen suhdanteisuus, jatkuvasti vaihtuva työporukka, epästabiilit olosuhteet sekä yhteysongelmat työmaalla.

Työmaalla syntyy hukkaa jatkuvasti ja tässä tutkimuksessa keskitytään ajanhukkaan, joka johtuu heikosta kommunikoinnista ja puutteellisesta tiedonkulusta reaaliajassa. Tutkimus rajoitetaan rakennusvaiheeseen eli työmaatapahtumiin. Tutkimus on kaksiosainen sisältäen kirjallisuuskatsauksen ja empiirisen tutkimuksen. Kirjallisuuskatsauksessa käsitellään kommunikointia ja siihen liittyviä teknologiaratkaisuja, määritellään hukka ja tarkennetaan ajanhukka sekä lisäksi tarkastellaan jo tehtyjä tutkimuksia tehokkuudesta ja kommunikoinnista työmaalla.

Empiirinen tutkimus toteutetaan suunnittelutieteellisenä tutkimuksena kohdeyrityksen nykytilannetta tutkien. Ensimmäinen vaihe oli haastattelut, ja jo tutkittujen ongelmien sekä oman kokemuksen perusteella tehtiin haastattelukysymykset. Haastateltavia oli 32, joihin kuului työntekijöitä, työnjohtajia, vastaavia työnjohtajia ja työpäälliköitä. Haastattelujen lisäksi työnjohtajille ja työmaavastaaville lähetettiin kysely, joka antoi kvantitatiivisemman tuloksen. Haastattelujen ja kyselyn tavoitteena oli kartoittaa nykytilannetta ajanhukan synnystä, digitaalisten laitteiden käytöstä työn tukena, tiedonkulusta ja kommunikoinnista.

Haastattelujen avulla löydettiin suurimmat hukan aiheuttajat ja tiedonkulun sujuvuuteen vaikuttavat tekijät. Hukkaa aiheutui haastateltavien mukaan esimerkiksi huono suunnittelu, tavaroiden ja ihmisten etsiminen sekä työmestojen epävalmius. Lisäksi ilmeni ongelmia reaaliaikaisten havaintojen teossa, sekä se ettei suurin osa työntekijöistä käytä puhelinta työmaalla. Kehitysehdotukset pyrkivät vähentämään kynnystä tekemään reaaliaikaisia havaintoja, parantamaan tiedottamista sekä vähentämään käytettyä aikaa etsimeen.

Avainsanat ajanhukka, kommunikointi, tiedonkulku, tehokkuus, reaaliaikaisuus

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The low productivity of the construction industry has been in the headlines for years and now companies are waking up in the reality and become interested in enhancing the productivity. Lean theory enables to find waste sources in production and to replace non-value-added activities by value-adding activities. In the construction environment, the challenges are cyclical nature of construction, continuously changing working group, unstable environment and connection problems on construction site.

Waste happens constantly and this research focuses in time-waste caused by lack of communication and real-time information flow. The research was limited to building phase, when work is ongoing on construction site. The research has two parts: literature review and empirical research. The literature review concerns communication and technological solutions concerning communication, defines waste and especially time-waste, and explores existing research concerning productivity and communication on a construction site.

Empirical research is design science research observing current situation of a case company by interviewing and piloting. The first phase was interviewing and the questions were based on existing problems according to the literature and own experience. Interviewees were 32 including site workers, site managers, responsible site managers, and construction managers. Additionally, to the interviews, a survey was sent for site managers and responsible site managers to get more quantitative results. The objective of the interviews and survey was to chart nowadays' situations of what kind of factors cause time-waste, use of digital tools to support work, information flow, and communication.

The major time-waste causes and factors affecting information flow were found by way of interviews. According to the interviewees, time is wasted because of poor planning, searching materials and people, and working places' unreadiness. In addition, many does neither use phones on a construction site nor pass the information in real-time. The solution proposals try to ease to make real-time observations, enhance informing, and decrease time used in searching.

Keywords time-waste, communication, information flow, productivity, real-time

Preface

This thesis got inspiration from my own experience on a construction site as too much time was used in searching people and the communication was challenging. NCC had also a need to improve the real-time reacting to reduce waste. In the meeting with my supervisor, professor Olli Seppänen, came up that Aalto University had a location system for construction sites in order to reduce time-waste and combining these two ideas – time-waste and communication problems – this thesis had the subject. Olli Seppänen contacted Movenium (today Visma) to make collaboration and they gave their location system that I piloted on one NCC construction site. My thesis advisor at NCC was the development manager, Jan Lund.

The writing process was challenging and in the end, the pressures were high as I had to work and go to school. Anyway, I enjoyed making this research and I learnt a lot about time-waste, people's attitudes, and I also improved my English skills. Because of the interviewing process, I had an opportunity to get know new people. I want to thank Olli Seppänen who gave me constructive comments, always answered to my questions, and taught me about academic writing. Then I want to thank NCC for financing this thesis and giving me a working place and computer. I want to thank Jan Lund who asked about my progress every day in the office and gave me peer support and tips.

I want also to thank my friends and sister who reminded me to keep my free-time and gave me something else to think. The last, but greatest, thanks belong to my parents who were always interested on how my thesis was advanced but also have been irreplaceable support during my education and have encouraged me to try new things. I have been able to ask my dad anything about physics and other courses, and my mom has helped me with the master's courses and especially during this thesis she has been my mainstay. Thanks to my parents I am on this route.

Espoo 27.3.2018

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List of abbreviations and symbols

ERP	Enterprise resource planning
ICT	Information and communications technology
IFC	Industry Foundation Classes
BIM	Building Information Modeling
GDPR	General Data Protection Regulation

Introduction

1.1 Background of the study

For four decades, the productivity of the construction industry has been in decline whereas the other industries have been in a rise (Aziz & Hafez, 2013). The figure 1 shows the low productivity of Finland and how the total productivity of industries have been rising.

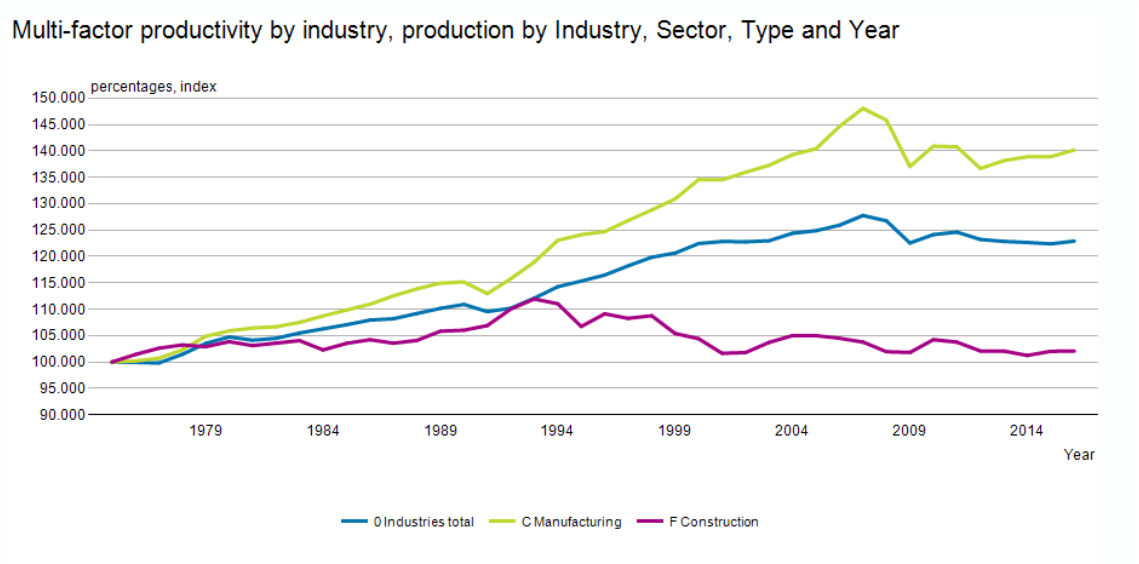

Figure 1 Multi-factor productivity by sector in Finland 1976-2016 (Statistics Finland, 2017).

It is possible to enhance productivity by improving labor performance (Aziz & Hafez, 2013). The growth of labor productivity in construction industry has been, and still is, poor and meanwhile demand of the new buildings, infrastructure, and industrial installations is increasing (Barbosa, et al., 2017). That growth is shown by many researches, for example in the study of Koskenvesa, sampling an amount of direct work shows the 1 % growth in productivity since mid-70's (Koskenvesa, et al., 2010, p. 478). In the Haas' study, the gathered data of sampling shows the slow progress of the productivity (Figure 2) (Haas, et al., 1999). The European Productivity Network, EANPC, has defined the productivity as a residual value, which is inexplicable after taking the growth of factors of production into account (Pekkanen, et al., 2006).

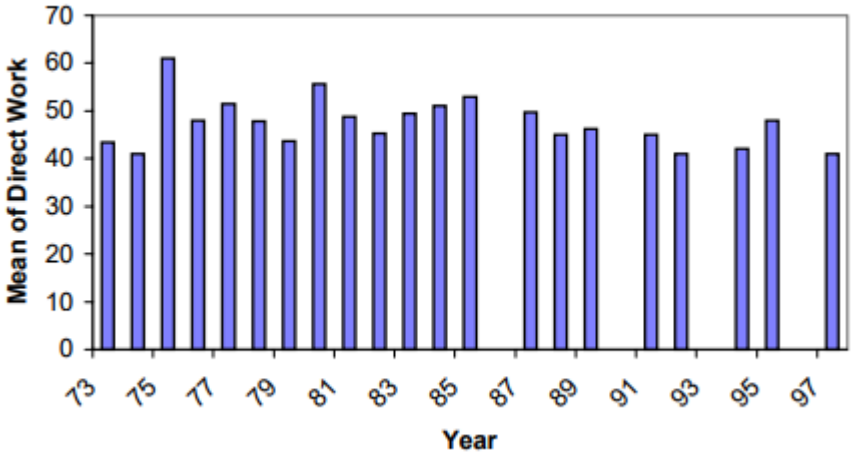

Figure 2 An Annual Sample Mean of Direct Work in Austin presents the low development. (Haas, et al., 1999).

The construction project is a unique and the building process varies always. The factors such as changing weather and geography increases the uniqueness. Some find the nature of construction industry attractive but instability affects the productivity. (Allmon, et al., 2000) The construction process includes various phases and processes, several parties, different stages of work, and also a great support from the public or private sector. The success depends on many factors such as the quality of the management and also technical and organizational performance (Takim & Akintoye, 2002). The productivity can be measured at macro- or micro-level.

Looking at macro-level, the productivity depends on how much money is spent on the production. Macro-level contains labor legislation and contracting. (Dozzi & AbouRizk, 1993) The factors come mainly from out of the project, such as weather, environment, legislations, economic situation, and political affecters (Bing, et al., 2005). Micro-level as for concentrates on project operation and management on a construction site (Dozzi & AbouRizk, 1993). Micro-level contains responsibilities, working methods, and coordinating (Bing, et al., 2005). This thesis concentrates on studying productivity at micro-level meaning activities on a construction site and focusing on time use in individual level.

The industry is competitive so companies need to focus on productivity to survive in the business (Park, 2006). Lean construction provides tools to enhance the productivity of both simple and complex projects. Lean construction projects have clear objectives during the whole construction process from designing phase to the end-product. (Aziz & Hafez, 2013) The principles of construction phase are reducing non-value-adding activities, increasing output value of customers' requirements, reducing variability and cycle times, increasing the transparency, and improving the flow management. The tools and methodologies for production are e.g. JIT (Just In Time), TQM (Total Quality Management), time based competition, visual management, process redesign and TPM (Total Productive Maintenance) (Koskela, 1997). The construction projects that follow lean methods are in general easier to control, safer, and the quality is better (Aziz & Hafez, 2013). To ensure the safety, communication between all the parties must be effective (Dainty, et al., 2006).

An effective communication culture is required to achieve goals such as high productivity and profitability, especially when the environment is complex and project organization changing. People come from different cultures and their understanding of the communication might differ. The challenge for the construction companies is to ensure that the multiculturalism does not harm the communication (Dainty, et al., 2006).

In Grunig's communication management book the main question is: "How does communication affect the achievement of organizational objectives?" Public relations depend on communication. The communication scientists, who have studied communication behavior, have discovered that whether people do not know about the problem or dominant situation, they are unwilling to involve in it (Grunig, 2013). Another description of an effective communication is that people can express their opinions and ideas, and meanwhile understand others' opinions. Communication is a learning process in which a knowledge improves (Dimbleby & Burton, 1992). A poor communication and lack of sharing information lead to time-waste impairing the total project performance (Hudgens, 2007).

Digital tools have potential to improve communication and interactions. One significant problem in the construction industry is lack of implementation of digital devices and applications (Puhto, et al., 2016). Today the digitalization level is still low in construction industry. McKinsey (2016) has made a survey of digitalization in different sectors. The figure 3 present six fields: ICT, finance and insurance, basic goods manufacturing, education, construction and finally agriculture and hunting. Construction and agriculture and hunting are the last ones of all the sectors in the digitalization.

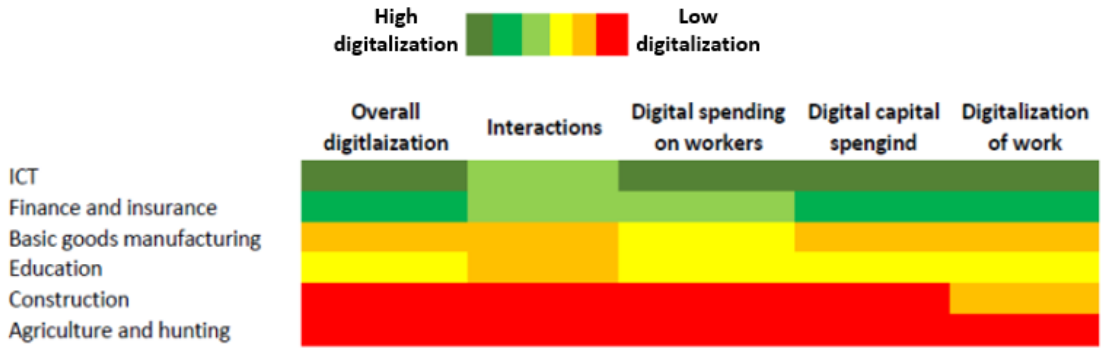

Figure 3 McKinsey Global Institute industry digitalization index, modified. (Agarwal, et al., 2016).

The digital tools provide controlling the project. The projects are getting more complex, and the mode of operation must be changed. The investments of digitalization should be more remarkable (Puhto, et al., 2016).

In a construction project, many activities consume time and effort but they do not add any value for the project. In a construction project not only the waste of material but also many activities, such as repairing, delays, waiting, and other unnecessary activities do not add value to the project. All the project members – suppliers, clients, and labors – must detect the waste while it occurs (Alwi, et al., 2002). The waste should be on focus on a site and considered as important subject as those that are necessary for the project (Formoso, et al., 1999).

1.2 Research objectives

The objective of this study is to find out which kind of factors affect a worker's efficiency and how it can be measured. Productivity of an individual worker requires investigation at micro-level.

As lean production is focused on eliminating waste, time must be taken account while concerning the concept of the total waste (Kalsaas, 2013). Another objective is to find out whether people understand the concept of waste and could recognize the reasons for non-value-added activity meaning that which kind of factors cause time-waste. Based on the results, the aim is to find ways which improve the communication and information flow[1].

As described in the previous chapter, a poor communication and intercourse result in ineffective work, meaning that time is wasted. In principle, most of the problems are causes of lack of information and ineffective communication skills. Here, the objective is to figure out what is the role of communication as a waste factor on a site.

The construction industry is still old-fashioned, but digitalization is starting to get a foot in the door. The technology advantages enable to evade scenarios that are impossible to see in traditional methods in advance during the construction phase. Furthermore, the objective is to see what is the role of technology as supporting communication. This thesis offers an overview of the dominant problems, and the goal also as a researcher is to recognize what is necessary to change. The solutions are found in the literature and in the empirical study.

The main research question is:

> How could time-waste be reduced by solving communication problems in a construction project?

And the sub questions are:

> Which kind of factors affect one worker's effectivity?
>
> What is the role of communication as a factor in time waste?
>
> How the digital tools support communication?

1.3 Research framework

A general building process starts from design phase, after that is production phase and the last phase is a maintenance and repair phase. This study is limited in the building production phase, which includes all the steps between pile driving and commissioning. On a construction site, there are main contractors and several subcontractors from several companies. In addition to them, the main contractor co-operates with design teams and customers every day. The building production phase has many challenges in the communication because of the uniqueness and complexity of the nature of the continuously

[1] Information flow is related to the communication, as it means how the information is transferred to the project members (Dozzi & AbouRizk, 1993).

changing working groups including different languages and cultures, and unstable working environment (Dainty, et al., 2006).

This study focuses on a real-time waste, and especially waste that is caused by poor information flow and communication problems. The waste is defined in chapter 2.3. and the work-time waste is defined further in the next chapter. The researches covered in this thesis concern the time-waste in construction site, real-time waste, communication problems, and productivity of the workers. There are studies about time-waste on a construction site, but usually they focus on material searching or logistics problems. The researches concerning the communication are focusing on design and planning phases. Earlier studies will aid in finding the communication issues, such as when and why waste happens, and how communication could be improved to reduce the time-waste.

In this thesis, the specialists are people who work on a construction site: site workers, foremen, site managers, and construction managers because the waste happens during a working day on a construction site between the project members.

1.4 Research method

This thesis is a design science. Design science research is used in many fields, e.g. architects, engineers, artists, and others use it. The focus is on creation and function, and the goal is to solve a relevant and important problem by new artifacts[2] (Geerts, 2011). An artifact needs to be new and innovative, in order to solve a problem or if a problem is already solved, the artifact must be a more effective way to operate. Thus, the design science is a problem-solving process (Von Alan, et al., 2004). The design science research guideline has following steps:

1. Problem identification: To understand the existing problem, study current solutions, and justify the value of a solution.
2. Define the objectives of a solution: To know what needs to be done in order to solve the problem. To get to know methods and theories, and technologies which assist in achieving the objectives.
3. Design and development: To create an artifact that solve the problem. It can be constructs, models, methods, or instantiations which solve the problem.
4. Demonstration: To prove that the artifact works.
5. Evaluation: To measure how well the artifact works by comparing the results and objectives.
6. Communication: To share knowledge about the problem and solution, and also the effectiveness, novelty, and utility.
   (Geerts, 2011).

The research questions are related to the time-waste and communication problems and a design science method affords an approach which takes account the existing knowledge and solve problem by actions. According to the description of design science method: the

[2] *An artefact/artifact is an object made or modified by human workmanship, as opposed to one formed by natural processes* (Thesaurus)

solutions which afford reducing time-waste might already exist, but are not in use effectively or they need to be new innovative. As the time waste is hard to recognize and measure because it is invisible, it is relevant to understand in which actions the time is used and which kind of factors affect negatively the construction process (Serpell, et al., 1995).

The thesis consists of a literature review, empirical research – including interviews and survey, and piloting –, solution proposals, and conclusion and proposals for further studies. The existing literature affords to understand what already has been discovered, and the empirical research as for takes account the current situation from the construction site. Finally, the results of both parts will be concluded.

The literature review displays the present situation of the productivity, which subsequently leads to the issues of waste and communication. The main purpose of the literature review is to explain the effects of waste on the productivity of construction industry. The literature part also deals with discovered technology solutions and developing ideas.

The scientific of the references affect the reliability significantly. To find academic articles, Google Scholar was the first search engine. Through Google Scholar, the access to "Taylor & Francis", "ProQuest", "ScienceDirect", "ASCE library", and "ResearchGate" was obtained. These offered various scale of documents. Also, different academic journals, such as "Lean Construction Management", "Automation in Construction", "Journal of Information Technology in Construction", and "Construction Management and Economics" were used. Because the theme is under the lean umbrella, the International Group of Lean Construction conferences afforded many academic proceedings.

The first part of empirical research (interviews and a survey) is divided in two parts, making a survey beforehand to get to know the present situation, and then proposing the possible solutions and possibly gather the information of how they work. Interviewing people who work on a construction site provides charting the situation on a site. The goal is to know whether they can recognize wasted time during a working day, and to ask how communication works on construction site between managers, and between managers and site workers. It is relevant to investigate how the opinions and perceptions differ between site workers and foremen.

The interviewing process is described more detailed in the chapter 3.1. With an interview, the purpose is to get broader understanding because an interviewee can give a specialized opinion, which does not come up as well in a survey. The survey is made anonymously which ameliorate people to be honest and the gathered data of the survey is more quantitative. The survey does not suffice in the research while both qualitative and quantitative data are required. Interviewing gives more specific answers, and both interviewer and interviewee can define a question or an argument. According to Saunders et al. (2009), managers are more likely to answer in the interview, when the topic is relevant to their work and is interesting, and meanwhile they do not need to write anything down. Several researchers have noticed the same phenomenon. The interview enables explaining the purpose of the interview and the object in which the information will be used.

Piloting a location system was the other part of the empirical research. The process is described in detail in the chapter 3.10. Piloting was made on a NCC construction site in Laajasalo together with Movenium (today Visma). The location system as known as tracking system is described in the chapter 2.7 in detailed.

To gather some experience of the location system, a doctoral student Jianyu Zhao was interviewed about his doctoral thesis which is dealing the time-use of workers. Additionally to interviewing that piloting project, a development chief of Movenium was interviewed in order to know how the location system will be developed.

2 The effectivity of a worker on a construction site

2.1 Factors impacting productivity of one worker

The construction industry is a labor-intensive sector: the efficiency and performance depend on human actions (Jarkas & Radosavljec, 2013, p. 1071). Each time the building process is different as the construction projects are unique. Different factors increase the uniqueness affecting the productivity at the same time. (Allmon, et al., 2000) Herbsman et al. (1990) have divided the factors in an organization between production factors, labor factors, and social factors. This thesis concentrates on employee's effectivity at micro-level which is under the labor factors -umbrella. To see which kind of factors affect performance, efficiency, and motivation; workers are the primary source to find them (Dozzi & AbouRizk, 1993). The difference between efficiency and performance is that performance factor is one tool to measure labor productivity whereas efficiency is often understood as labor productivity (Thomas, et al., 1990).

Many complex and interdependent factors affect the productivity on a construction site (Dozzi & AbouRizk, 1993). These factors can be called also success factors affecting the performance which leads the project success which as for is related to the efficiency and effectiveness of the project. On a construction site, e.g. safety, communication and reporting, good working relationships, labor utilizations, cost controlling, and efficiency are the ones that contractor have an influence. (Takim & Akintoye, 2002, pp. 551-553) Labor effectiveness depends on several factors including e.g. environment, job security, motivation, and physical limitations. The management practices control the labor efficiency containing planning, data collecting, scheduling, and controlling. It is noteworthy that at micro-level, companies and individuals can improve the productivity. (Dozzi & AbouRizk, 1993)

Improving the labor productivity, the focus must be on site management, as an ineffective management is underlined to be one of the most remarkable reason for low productivity (Allmon, et al., 2000; Thomas, 2015). Productivity depends on the workforce and leading and instead of blaming incompetent or unmotivated workforce for the waste, the management is ineffective (Haas, et al., 1999; Formoso, 2015). In a project phase the management structure plays a role as a performance indicator and usually high efficiency is related to the strong management (Takim & Akintoye, 2002, p. 550).

Planning is one of the main responsibilities of managers and without preplanning the tasks, misunderstandings and misinterpretations appear (Koskenvesa, et al., 2010; Arayici, et al., 2012). Many waste causes are related to the poor planning, and according to Serpell et al. (1995) the main problem is the lack of time reserved for planning (Serpell, et al., 1995). Planning and preparations of task are unconditional because otherwise work is started without all the required inputs or finished insufficiently (Koskenvesa, et al., 2010). In Finland, the Ratu-data provides information for production control and planning. Site managers may use Ratu-data to ensure that working methods are uniform and safe in order to achieve the common goals. In order to reduce misinterpretations and misunderstandings, Ratu-data is available in different languages. (Rakennustieto, 2018)

Because of the multiculturalism on a construction site – meaning different languages, cultures, and educations – the communication is challenging. One of the most challenging management task is to gather group of people who have never worked together and create a plan that each member executes. (Dainty, et al., 2006) The work climate needs evaluation in order to study workers' satisfaction (Serpell & Alarcon, 1998, p. 217).

Site managers do not only support workers but also motivate them. Motivation is one of the most influencing factor to increase productivity. (Herbsman, et al., 1990) Especially it is an increasing factor from workers' perspective. High motivation increases also the job satisfaction and therefore people make the work more effectively. (Jarkas & Radosavljec, 2013, pp. 1070-1074). Motivation depends on productivity but also increases the productivity meaning that they are interdependent. Each smaller and larger, positive, and negative actions affect the motivation of workers to cooperate and work. (Kazaz, et al., 2008) It is unnecessary to solve productivity problems whether worker's motivation is not taken account (Halligan, et al., 1994). Safety and health conditions are among the most influencing motivation factors on a site and a management has a significant role in the safety performance (Sawacha, et al., 1999; Kazaz, et al., 2008). Gathering real-time information is required in order to study which kind of activities increase the safety risk (Teizer, et al., 2010, pp. 630-631).

Pro-active real-time tools are useful to warn workers sending an alert if some equipment is too close. Sending and also receiving the information in real-time is essential because the project proceeds constantly. (Teizer, et al., 2010, p. 631) Flaws reporting needs to be done immediately at the stage to improve present project but also to learn for the future projects (Alwi, et al., 2002). Because of the lack of sharing information, the waste happens on a site (Hudgens, 2007). Controlling the information flow needs then to be focusing concerning the whole production process (Ballard, 2000, p. 2:16).

The lean construction is not yet in operation widely, but because of the great success of the methods in the manufacturing industry, the construction industry has taken put the theory in operation (Aziz & Hafez, 2013). According to the study of Salem et. Al (2006), the lean tools from manufacturing process will work in the construction process as well. Lean construction tends to improve the following scopes:

- Flow variability
- Process variability
- Transparency
- Continuous improvement.

These all have communication as a factor which requires a change and enables the improvement in the project. (Salem, et al., 2006, p. 172)

2.2 The methods to estimate productivity

The construction productivity needs to be investigated in order to know which factors affect it and to understand the behavior of the construction field. The results affect directly the factors of a process success on a construction site including labor and resource management, scheduling, and estimating budgets (Herbsman, et al., 1990). Measuring the

productivity on a construction site, the focus must be in workers and in their performance (Pekkanen, et al., 2006).

Ratu-database is a guide for planning the building phase and each task. Ratu-database provides a guideline to see how much resources, such as time, money, and work, one task requires. (Rakennustieto, 2018) It consists of task planning, scheduling, cost estimation, and also provides information concerning quality, safety, and environment (Koskenvesa, et al., 2010, p. 480). Lack of planning, flaws in the management, designing problems, and others increase the waste on a site which need to be taken account on a site while calculating the productivity (Formoso, et al., 1999).

There are two types to measure productivity: Total Factor Productivity (TFP) and single factor productivity. TFP contains labor, equipment, materials, and capitals. (Park, 2006). Micro-level investigation provides to see daily or monthly productivity. On a construction sector as for the focus is on labor productivity meaning units of work per unit time. (Halligan, et al., 1994) Single factor productivity is simply input over output and it can be measured with following formula (Park, 2006):

$$Labor\ productivity = \frac{Input}{Output} = \frac{Actual\ Work\ Hours}{Installed\ Quantity}$$

Labor productivity shows efficiency on a site (Thomas, et al., 1990). In that equation the lower the measurement, the better performance in the productivity (Park, 2006). There is no standard way to measure the labor productivity, so some like to inverse the equation meaning that bigger productivity means better performance (Thomas, et al., 1990). The productivity does not only include necessary activities and items but like Formoso, et al. (1999) mentioned that the unnecessary items must be taken account as significant factors as the necessary ones.

While estimating the productivity it is notable not to confuse with profitability. Profitability takes account financial effects and productivity the physical phenomena. These are not dependent on each other as some reasons might change the company's profitability but not affect productivity. (Pekuri, et al., 2011)

2.3 Defining the waste

Lean definition for waste is "Waste is a factor that does not support lean principles and reduces the value of the product" (Hicks, 2007). There are two types of activities in production: value adding activities and non-value adding activities (waste) (Koskela, 1997). Waste adds costs but no value to the product (Aziz & Hafez, 2013). It is challenging to define waste, because in the manufacturing processes, waste is visible and understood as an eliminator of continuous workflow. Whereas in the information management, the waste is invisible. (Hicks, 2007) In production a failure of seeing what customer requires is waste (Howell, 1999).

In the production, seven wastes are defined: overproduction, waiting, transport, extra processing, inventory, motion, and defects (Hicks, 2007). Koskela (2004) has described the eighth waste in a construction production called "making-do". It means that a job should not start before the preparations are ready. Preorganizing the interfaces between tasks

increases value-added work to the process. If a worker goes to the site and cannot start his work the lead-time increases, the person becomes frustrated, and the time useless. If the work place is not ready they move to the next task, and the previous place will stay incomplete. Nevertheless, on a construction process some waiting exists anyhow.

For lean construction, the principle is to recognize and reduce waste but the sources might be as challenging to identify as the waste itself (Ballard & Howell, 1994; Hicks, 2007). Usually the waste is understood as a subject that can be just removed and disposed in landfills, and this might be the case when the form of waste is material or some other visible and solid. The waste is usually measured by costs but effectivity of the equipment and labor are harder to measure. (Aziz & Hafez, 2013) Actually many aspects affect the waste: quality problems, constructability, material management, non-productive time, and safety issues. These are often hidden in a construction process even their amount is considerable. (Koskela, 1992)

Polat and Ballard (2004) have two components of waste: material waste and time waste which is described in more detailed in the next chapter (Polat & Ballard, 2004). It is relevant to see what a good performance requires and after recognizing, the project management need to find solutions how to improve the operation (Aziz & Hafez, 2013). In the building process, from the beginning of the project the foremen need to handle waste. Ferguson (1995) has presented a practical guide for transferring waste, which is visible. It is a checklist that must be completed before accepting the waste. The practical guide could be used as well to identify and remove time waste (Table 1).

Table 1 The comparison between transferring the waste and removing time waste.

TRANSFERRING THE WASTE (Ferguson, 1995)	**REMOVING TIME-WASTE**
Identify the waste	Recognize the wasted time and non-added value work
Quantity of waste	Quantity of wasted working hours
Containment of the waste	Nature of the waste: ineffective work (re-working, working slowly) or inactive time idle time, waiting, resting)
The time and place of transfer	-
The name and address of the transferor	The reasons of the waste (poor planning and information)
The name and address of the transferee	The consequences of the wasted time (extra working hours, costs, delays)

Lean construction projects replace the non-value adding activities by value-adding activities and utilize the technologies to design and reduce costs (Aziz & Hafez, 2013). To enhance productivity and eliminate waste the solution is not to reduce time and costs, because that does not guarantee improvements. Whereas having clear goals, maximizing

performance of the customer, and managing the product and project during the whole process, enables the control over the project. (Howell, 1999)

2.3 Work-time waste

Even if the construction process is planned to be comprised of value adding activities, it does not lead automatically value adding process time. Polat and Ballard (2004) have defined time waste types: stoppages, waiting periods, clarifications, rework, ineffective work, interaction between several professionals, delays, variation in information, and equipment abuse.

Serpell et. al (1995) have divided time waste in to two combinations: work inactivity and ineffective work. Work inactivity includes waiting time, idle time, traveling, resting, and physical needs. Ineffective work as for reworking, working slowly, errors, and inventing work. These are nonproductive activities which affect the total production. Salem et al. (2006) mentioned that e.g. reworking is more challenging to avoid in the construction industry as only one product is delivered. Instead in the manufacturing process, reworking is generally avoided, as the product is rather discarded than reprocessed.

The waste causes can be controllable or non-controllable. Flows, conversion processes, and management are all controllable. Flows mean construction resources and information, conversion processes mean processes during which the flows are transformed into completed products, and management is responsible for the process performance and makes decision that determine why things are done. (Serpell & Alarcon, 1998, pp. 215-216) Again, the importance of the management is highlighted. The flows and conversion should be controlled by managers, because they have resources. All the project members have an influent but the managers are vanguard. Whether the managers have poor competence in delegation, guiding, planning, or communication, the project does not have a strong basis. Managers should take care of flows in order to ensure the information flow and the communication work.

Studies of productivity have often been made from management's perspective because workers might find offensive to be observed, or the work is interrupted while tracking. Nevertheless, to study labor efficiency, workers are in the position where the waste and gains happen. (Dai, et al., 2009) It is important to notice that wasted time is not directly result of workers' laziness or incompetence. It is caused by dragging materials all over the work space, poor planning, and communication between parties. Time is used to find materials being not only frustrating but also unproductive activity. (Anon., 2017) Measuring waste in such a great concept as a construction production is challenging, and many of researches have focused on some sort of waste. Kalsaas was dealing with few researches and his main question was: "How do we measure work-time waste at the production level on the construction industry?" (Kalsaas, 2013)

The work sampling technique is a method to measure labor productivity. Sampling means that workers are observed and actions recorded. (Haas, et al., 1999) The goal is then to measure how much time is used in one operation and then analyze how effective the operation was. The first step at studying productivity is to define the content of activities of

workers and then make random observations in the field during operations (Dozzi & AbouRizk, 1993).

The distribution of work task in general is between three categories: direct work, supportive work, and delay. Depending on a job description, these three classifications have different contents. One general distribution is shown in the table 2 below. (Haas, et al., 1999) Serpell et al. (1995) presented the limitation that sampling has: it does not show origin of waste precisely, it does neither provide production rates, but measures only work time utilization nor measurements of waste of materials. According to Kalsaas (2010) one risk is that the workers might change their attitude and behavior, but researchers have assumed that to be limited, so it is not a remarkable risk. The workers under supervision are from a trustful and safe environment so the risk of irrelevant results is minimized.

Table 2 The three categories of activities of workers. (Haas, et al., 1999)

Direct work	• productive actions • picking up tools at the working area • measurement on the working area • holding materials in the place • inspecting for proper fit • putting on safety equipment • cleaning up
Supportive work	• supervision • planning • instructions • all travel • carrying or handling materials and tools • walking empty-handed to get tools and materials
Delay (waste)	• waiting for the place to be ready • standing • sitting or wandering • personal time • late starts and early quits

After dividing the activities in three categories, researchers have defined the content of the waste in detailed. Kalsaas identified time-waste as a time wasted in logistics, poor information flow, and searching materials. In the study of Josephson and Saukkopiiri (2005), unutilized time included personal needs, non-work-related discussions, late arrival, early departure, and extended breaks. In the research of Thune-Holm and Johansen (2006), observations did not make difference between productive and counter-productive

work which means reworking. (Kalsaas, 2010) Haas identified the direct work as erecting framework, tying reinforcing steel and placing concrete. The support time was transporting materials and tools and getting instructors. The empty time was identified as waiting and taking breaks. (Haas, et al., 1999) In the study of Serpell et al. (1995) non-contributory work included waiting, idle time, resting and reworking, contributory work as far transporting, cleaning, receiving instructors, measuring and other specific activities and finally productive work was the direct work.

2.4 Previous researches about time-waste

In the table 3, different researches about labor productivity are presented. The first column shows the references, the second column presents the purpose of the study, the third column describes the research method, and the last column shows the results of the research.

Table 3 the previous researches regarding the productivity and wasted time.

Reference	The purpose of the study	Research method	Results
Kalsaas, 2010, IGLC	To measure time waste in construction and quantify it. Lack of making-do leads to time waste.	Collecting working hours from bosses. Gathering the data of 30,000 man-hours of concrete work, ventilation, electrical work, plumbing and carpentry.	Time was wasted in: ○ planning 4,6 % ○ time waste 4,7 ○ work fragmentation 3,2 % ○ performance related time waste 1,5 %
Kalsaas, 2010, IGLC	Micro mapping of working time	Students observed 11 days electricians, plumbers and carpenters in the Havlimyra construction project by registration every five minutes between 7 and 15 o'clock.	○ Direct work of all crews 49,1 % ○ Personal time 13 % ○ Breaks 10,6 % ○ Handling of materials 9,7 % ○ Work planning and meetings 5,9 % ○ Waiting 4 % ○ Reworking 3 % SUM UP: 17 % of waste, value-adding work 49 % and supportive work 34 %

Josephson and Saukkoriipi, 2005, Swedish study	Measuring working time, because the researchers have identified waste to be 30-35 % of the total costs.	Observing time use of construction workers for 22 days.	○ direct value-adding work 17,5 % ○ preparations 45,4 % ○ pure waste 33,4 %
Thune-Holm and Johansen, 2006, Skanska Norway	Measuring time waste, but not focusing on how the work is conducted.	Observing concrete workers (2 measurements) and carpenters (4 measurements). Registration 3-5 points per hour, and after observation, add them together.	○ Concrete workers: 65,1- 69,5 % productive time ○ Carpenters: 59,4-70,7 % productive time
Koskenvesa et al., 2010, University of Salford	Examine labor productivity and waste in production phase	Collecting data, such as daily or weekly working hours, time study methods and activity sampling of 12 tasks 1975-2008.	○ Labor productivity increased 1 % per year since 1975 ○ Not remarkable change in labor productivity ○ Productivity in mounting of large-scale elements has decreased
Haas et al., 1999, University of Texas	Study long-term period productivity by covering different fields	Sampling different tasks from 72 projects 1970-1998. Collecting working hours, time study methods and activity samplings from at least 10 sites.	○ Annual direct work mean values varies between 41 % to 61 % ○ Labor costs have dropped and output change increased in many fields
Serpell, A, University of Chile Venturi, A & Contreras, J,	Firstly: Classify construction waste and their main causes.	Work sampling in 17 construction projects by 7 companies.	○ Non-contributory work 25 % ○ Contributory work 28 %

Catholic university of Chile	Secondly: Statistics of the frequency and relative importance of the waste.		○ Productive work 47 %
Pekkanen, et al., 2006, VTT	Study development of job descriptions.	Collecting and analyzing data of productivity of different tasks 1997-2004.	○ Performances have been improved 20-35 %. ○ To demonstrate: installing elements and reinforced columns 25 %, task of partition 31 % and screeding 32 %. ○ Customers more and more demanding, and they prefer site construction with pre-assembled block
Wikforss and Löfgren, 2007, a project of building and renovation of the National Defence College and the Swedish Institute of International Affairs in Stockholm	To see how communication works on design phase between all the parties when time is a crucial factor.	Looking how planned practices was realized.	○ Shared common sites were not used as planned, instead the informal, direct channels were in use ○ Time deadlines, financial pressures and shortcomings affected relations and cooperation between project members
Wikforss and Löfgren, 2007, building of the Sockenplan subway train station	Focusing on information flow during the design stage and to see how it is managed.	Looking how planned practices were realized and communication handled.	○ The information flow was uncontrolled ○ No one used a planned Interned based project management network

			○ The project network remained limited

The researchers have gathered the waste causes or significant findings. In the table 4 the findings are the results from the previous table and the causes explain why they occur.

Table 4 The causes of the finding according to the researches.

Reference	The findings	The causes
Kalsaas, 2010	○ planning 4,6 % ○ time waste 4,7 ○ work fragmentation 3,2 % ○ performance related time waste 1,5 %	○ Lack of materials and equipment ○ Unavailable working place ○ Errors made by others ○ Workplace unavailable ○ Inadequate drawings and missing drawings
Kalsaas, 2010, IGLC	○ Direct work of all crews 49,1 % ○ Personal time 13 % ○ Breaks 10,6 % ○ Handling of materials 9,7 %	Main causes of time waste are ○ 4 % of working time is waiting ○ 3 % of working time is reworking
Josephson and Saukkoriipi, 2006	Pure waste 33,4 %	○ Waiting 23 %
	Preparations 45,4 %	○ Preparations near the workplace 25 % ○ Handling of materials 14 % ○ Planning 6 %
Koskenvesa et al., 2010, University of Salford	○ Not remarkable change in labor productivity ○ Productivity in mounting of large-scale elements has decreased	○ development of technology and working methods increase performance ○ Prefabricated elements expedite the productivity of hollow slab mounting ○ Complexity of architecture and structures decrease installing large-size frameworks and sandwich elements

		○ Management skills and workforce issues affect the most in a changing environment
Haas et al., 1999, University of Texas	○ The productivity has not changed significantly	○ Depressed real wages ○ Technological advantages ○ Management has not been intensified
Serpell, A, University of Chile Venturi, A & Contreras, J, Catholic university of Chile	○ Non-contributory work 25 % ○ Contributory work 28 % ○ Productive work 47 %	○ Waiting time: • Lack of equipment 14 % • Lack of materials 12 % • Lack of supply 10 % • Lack of progress 18 % • Overmanning 27 % • Others 19 % ○ Idle time • Worker's attitude 20 % • Decision making 9 % • Overmanning 27 % • Lack of supervision 39 % • Others 5 % ○ Traveling time ○ Transporting time
Pekkanen, et al., 2006, VTT	○ Performances have been improved 20-35 %.	○ Buildings are more complex which pushes the technology to develop ○ the tools, scaffold and technology devices have developed
Wikforss and Löfgren, 2007, a project of building and renovation of the National Defence College and the Swedish Institute of International Affairs in Stockholm	○ Several plans, which were not followed or realized	○ Professionals did not meet in the same communication level ○ Several misunderstandings ○ A manager should make common rules and obey them
Wikforss and Löfgren, 2007, building of the Sockenplan subway train station	○ Common network was not used	○ The members did not use ICT, even it is a tool for direct contact and speed of communication

	○ Information flow was not controlled	○ The professional jargon

Each researcher had made some assumptions and were conscious about the result that were gathered. The Kalsaas (2010) micro mapping study was made at the completion phase, in which many different small jobs include. That leads to irregularity of observed tasks. Companies that prefer subcontractors are increasing. Observing subcontractors is not long lasting, and according to Koskenvesa economic situation affect labor productivity bit internal management skills and training have a value for real changes. (Koskenvesa, et al., 2010)

Researches show that the divisions between direct work, preparations, and waste have been similar since 1990's. As already in the chapter 2.1 the importance of planning was described, here many delays originate from poor planning, as the locations have not been ready and lot of equipment and materials not available. Waiting seems to be one repeating cause for time waste. Management skills are related to many causes.

Because the waste amounts have been parallel, a relevant assumption is that the same mistakes are repeated and the waste probably is not recognized. To minimize the waste, a documenting plays a significant role as recognizing the waste causes. The negative impacts should be recorded in order to learn in following projects and to react immediately during the present project. Waste documenting includes why, when, and where the problem occurs, who initiated the problem and how the problem was overcome. (Alwi, et al., 2002)

Accepting the non-value added work or non-productive work in the planning phase cause considerably the waste. The cost-estimation manuals have been in use for long time, but the problem is that they are not intended to estimate the productivity, but they assist the cost estimation between the tasks (Haas, et al., 1999). In average Ratu-data includes 30-60 % of non-productive times as known as waste (Koskenvesa, et al., 2010, p. 481). On a construction process some waiting exists anyhow (Koskela, 2004). Along Koskenvesa et al. (2010) the problem is that whether the waste is already accepted in the standards, it is admitted also in the production schedules, task durations, cost estimations, and contracts. A product management depends on the project management and all the aspects of production, such as flow, transformation, and value are meaningful for the success.

Usually higher productivity means the higher profitability (Rojas, et al., 2003). According to Haas' research, real wages have dropped significantly between 1974 and 1996. This is a result of the nature of the construction industry: the work is sporadic and the number of labor varies constantly because of the supply and demand. While the recession, the most skilled and hard-working employees are kept, so this means the workforce is more efficient, and it increases daily outputs. (Haas, et al., 1999)

It should be noted that high percentage of direct work does not guarantee high level productivity or the productivity level of a company does not mean that workers are efficient (Dozzi & AbouRizk, 1993; Allmon, et al., 2000). The working methods, used tools, productivity, and skills differ between workers meaning that a skilled worker can have a

same direct work rate than an unskilled worker. The direct work determines the efficiency of workers' working hours, so the construction productivity obviously rises as a result of the increasing direct work. (Haas, et al., 1999)

2.5 The role of communication as a factor in time-waste

Communication is a pipeline, where information flow comes across from one to another (Dainty, et al., 2006, p. 3). The description is impossible as the communication is an imprecise and extended concept. Communication provides interactions between parties and does not mean anymore physical face-to-face meeting, it can happen via technological applications. (Ochieng & Price, 2010)

In an organization learning happens constantly and without communication the information flow cannot proceed. A culture, in which the environment is changing and intercourse is dynamic, the communication means also managing the process. (Barker & Camarata, 1998). A construction project organization is a line organization, which means hierarchical (Wikforss & Löfgren, 2007). The communication is a tool for eliminating ambiguities and without collaboration a multifaceted project fails. The communication between the parties is not that simple because of the complexity of a building process (Ballard & Howell, 1998b).

In large projects the communication is problematic because the employees have different cultures and behaviors (Ochieng & Price, 2010). Because of the different languages, the terminology and words may have different meaning. Non-verbal communication including body language and other non-verbal signals as for lead to misinterpretations. (Dainty, et al., 2006, p. 61) Some inefficient communication methods in a project complicate achieving trust and confidence in a project team (Ochieng & Price, 2010).

Lean construction techniques have potential in the total process control. Unfortunately, implementing lean technique is not platitude globally even its goal is to eliminate waste (Polat & Ballard, 2004). Salem et al. (2006) implemented in one case project lean tools: Last Planner[3], 5S, fail safe for quality, increased visualization, huddle meetings, and first-run studies. The benefits were clear: the project was three weeks ahead and under the budget, but also the relationship between the general contractors and subcontractors was better. All of these had two common improved criteria: relation with other tools and communication. At the end of the project the subcontractors and general contractors had a better relationship. To condense, a good communication motivates both workers and managers (Dainty, et al., 2006).

The communication and the lack of it influences a whole project control. Last Planner is a tool for scheduling phases, and it also links the schedules between the tasks and ensures that the whole project is under control. A pull technique reduces overproduction, as tasks are defined so that their completion releases the work. In a team planning, all the project groups write a description of a phase and what is required to complete it. The next step is to move and adjust the sheets on the logic network. (Ballard & Howell, 2003) The Last

[3] The Last Planner is developed by Ballard since 1992 in order to improve the quality of planning weekly assignments (Ballard, 2000).

Planner is a collaborative scheduling process which demands each involved project member to participate. The limitations or conflicts are then possible to recognize and remove. (Seppänen, et al., 2010) Additionally to the cooperation, a construction site benefits from the Last Planner as the scope varies from 2 to 6 weeks (Aziz & Hafez, 2013). To condense, Last Planner provides better quality, knowledge, and communication (Salem, et al., 2006).

A good communication and sharing the information enable teams to find new solutions and also eliminate overlapping. On a construction site at the meetings members have a possibility to share their views but also that is an occasion to talk about the problems (Aziz & Hafez, 2013). There are two types of meetings: foremen have their own meeting every week in which they go through in a weekly level the work plans focusing on the coming assignments, then the other one is a daily morning briefing for the workers in which they go through the safety, housekeeping, and scheduling. Salem et al. (2006) implemented the huddle meetings in a case study. Foremen had "All-Foreman Meetings" every week and kept a daily briefing "Start-of-the-Day Meetings". The results of weekly meetings were positive because the overlaps and potential problems were identified. According to the job survey, 67 % or workers found daily briefings valuable but most of them prefer to talk directly to the foremen during the day.

The openness and seamless communication means that all the workers and other participants in the project can point out problems. This should be platitude, because it affects safety. The information should be transferred to all the levels of an organization, so that the flaws will be corrected and in future the site workers have an interest in telling about the defects. (Mohamed, 2002)

Information and technology improve the communication culture. Visualization provides more information for the project members and brings up the hidden problems. (Aziz & Hafez, 2013) As mentioned, a construction site as a working place is continuously changing and the job description varies. A sight is fast and the eyes are a significant channel of communication, and work as an observation tool (Ovaska, 2012). Visualizing the task before the work starts on a site decreases a large amount of rework (Li & Love, 1998).

In construction projects, like in production in general, the managers are expected to be in two places at the same time. They should be on a site coordinating the work and meanwhile at computer doing paper work. What makes a building trade ineffective is that the foremen must run to the site to find workers to give specific instructions when a complication appears. (Wikforss & Löfgren, 2007) Interruptions cannot be avoided, but the lack of interest in supervising, training, and caring can be. (Halligan, et al., 1994)

2.6 The role of technology to improve communication

The construction industry is changing globally because clients become more demanding and projects need to meet the demands more closely. This means that construction industry needs to be streamlined through a technology. (Bowden, et al., 2006) For 40 years, different kind of technologies have been applied to the construction projects without bringing any essential value. Even the technology advantages have potential in improving

the efficiency, they do not reduce costs and, at the same time, improve the management. (Aziz & Hafez, 2013)

Puhto et al. (2016) have written a digital report of the digitalization in the property and construction industries. In their survey they asked 600 companies – got 146 answers – about the present situation and the future of digitalization. The questions concerned what should be improved and which kind of factors are challenging. 20 % were digitally inclined companies which means that they had digitalization in their strategy and they want to improve and benefit of digitalization. These companies were large ones.

According to the study of Puhto et al. (2016) many companies find that the industry has not benefitted enough of the digital advantages. In the survey, the researchers asked how the companies benefit of digitalization. Six percent of the respondents felt that digitalization brought very significant benefits, half of the respondents felt that they had achieved at least reasonable significant benefits, and 40 percent found the benefits low or nonexistent. Anyway, the digitalization is seen as a possibility, not thread.

On a construction site, there are potential digital solutions for enhance communication but also technical challenges (Puhto, et al., 2016). ICT tools provide an intense way of communication, but they may rather bring chaos to the project team than produce seamless communication. ICT is a concept for controlling and tracking the whole communication and information flow but is often considered as only handling data, classification and modeling. Although it is a tool to share knowledge in an organization and to create an effective environment. (Wikforss & Löfgren, 2007) Using mobile technologies cuts retyping, rewriting, and the time used to retrieve the information. These affect the construction time and the capital costs so that the productivity increases. (Bowden, et al., 2006)

Technology increases productivity but also complexity as it requires effort in learning how to use new devices (Haas, et al., 1999). The challenges in digital developing in an organization result from lack of agility and technical know-how. Also measuring the benefits of digitalization is a block to develop the digitalization. (Puhto, et al., 2016) Nevertheless, adapting a new technology is unquestioning, because of the competition. The technology enables solving greater problems and estimating costs, especially labor costs. (Ochieng & Price, 2010) The developers in the construction site try to rethink construction industry. The reduction in construction time, waste, capital cost of construction and accidents, and the increase in productivity and predictability are common to most of the developers. These are possible to be realized by industrializing the building process and increasing technological advantages. (Bowden, et al., 2006)

In construction industry communication plays a critical role between management and customers. The communication between site teams and design teams is still traditional, using 2D drawings, face-to-face meetings, e-mails, and telephone. (Dainty, et al., 2006, p. 201) The more information is available, the more integrated is the field that facilitates the management of professional groups (Wikforss & Löfgren, 2007). Visualization tools reduce costs and also decrease the amount of rework as the rework is usually result of construction or design changes and errors. (Li & Love, 1998) Virtual Reality (VR) is a

combination of existing technologies such as designs and simulation. The VR can be described in many ways, here are couple of them: “a computer-generated simulation of three-dimensional environment, in which the user is able to both view and manipulate the contents of that environment” or “the science of integrating man with information.” (Bouchlaghem & Liyanage, 1996) With VR, the issues on a construction sites, such as logistic problems, processes, and engineering designs, can be seen and analyzed which as for improves the total control over the project (Goulding, et al., 2012).

Still today, paper plans are large enough and they are easy to handle, but with a small screen, the visible drawing is limited. The concentration needs to be in a style, how the information, such as drawings and schedules are presented on the mobile devices. Another notice is, that depending on what type of information is added, the inputting method varies. The information can be added from computer, with mobile phone on site, or by recognizing the voice. In order that the user gets all the benefits from the mobile: drawing, zooming, editing, making notes, and scrolling must be possible. (Chen & Kamara, 2008)

Workers need to be able to comment and point out the problems as easily as people from the office. Often the BIM models are only used at office, but actually the people on site have more experience than many of designers or managers. The models as a source of information on-site are replacing the papers that produces realistic visualization and rises the safety and productivity. (Woodward, et al., 2010)

Foremen run between the construction site and offices, it is ineffective use of resources. Most of the mistakes are result of lack of materials or drawings. The process will be enhanced by controlling the flows. (Ballard & Howell, 1994) The construction projects have a huge amount of information including e.g. plans, details, data of workers, and all the business information to control the project. The information should be distributed to the relevant people at certain time, and that is possible to make in real-time only via technology devices. (Hudgens, 2007)

Inefficient information sharing and lack of knowledge of the location of personnel, equipment, and building materials are significant causes for time-waste. Searching leads to the situation in which the information does not reach right people at wanted time. (Bowden, et al., 2006; Hudgens, 2007)

One solution for locating people and act in real time is GPS-based tracking system (Trimble, 2008). In the construction industry, the location-based solutions are rare. Only 14 % of 127 companies used much location-based programs or mobile applications, 33 % used rarely, 7 % had the system at piloting or developing phase, and the rest 45 % used never or could not answer. (Puhto, et al., 2016). GPS offers precise location data despite of the weather. Ambulances use the GPS-based AVL (Automatic Vehicle Location) to locate their vehicles which are the nearest for the accident place. The tracking system decreases time when the location can be found out from a device. (Trimble, 2008)

Vehicles and workers can be tracked as the tracking sensors can be attached on both (Zhang, et al., 2009). The management has an occasion to be more effective while knowing the movements and locations (Hudgens, 2007). The construction management could

use resource tracking in order to reduce waste, asses the productivity, and prevent accidents (Shen, et al., 2008). The system contains workers' time use and analyzing the data, managers can estimate the productivity (Zhang, et al., 2009).

The existing location systems differ as they are based on different technology solutions. The tracking system is a combination of radio frequency identification (RFID) and GPS. Tapp et al. made a patent 2012 for RFID-based tracking system. Their tags are radio frequency identification tags. A remote station reads and communicates using radio frequency or some other wireless communication method when a tag enters a certain area. This affords the real-time status of the location and after leaving the scene the tracking stops. (Tapp, et al., 2012) Outdoor the system works well, but in the enclosed building, RFID tags suffer from nearby metal items (e.g. reinforcement mesh, metal door) and due to requiring a strong communication network, the base stations are mandatory (Shen, et al., 2008). Hudgens has a patent 2007 for a method and system for context-sensitive, location-based information delivery on a construction site which identify users and their locations with an application. The system is based on an information appliance which works as an identification of a user. It warns a controller about the location-based safety violation and stores users' information by sending the data wirelessly. (Hudgens, 2007)

The implementation process of tracking system has challenges because of the unstable conditions, connection problems, and also the high costs of the technology (Shen, et al., 2008). The survey of Puhto et al. (2016) shows that companies are not willing to put resources on invocation of location systems: 21 % of 127 companies found that investing is unnecessary.

As the locating system is not yet legal as it gathers personal data of users which is forbidden, Data Protection Ombudsman (DTP) has gathered directives that must be realized before operation. In principle, an employer has a right to supervise where and how the work is done based on the management and supervising rights. The information of time use cannot be used as the basics of salary. People under supervision must know what kind of personal data the system gathers. (Tietosuojavaltuutetuntoimisto, 2014) EU have a General Data Protection Regulation (GDRP) in order to protect rights and freedoms by protecting the personal data. Gathering personal data provides endless amount of information but the regulation imposes limitations that the purpose of use must be specified and legal. (Nyrén, et al., 2014)

3 Empirical study

This thesis is made for NCC Building which is part of NCC Group. NCC Building is NCC's largest area of business and construct housings and offices. NCC Building operates all around the Nordic countries but the most important market is in Sweden. Company's strategy is to renew its industry and provide solutions that are in agreement with sustainable development. The five megatrends which revolutionize the building and property field are: urbanization, globalization, sustainable development, competition of professionals, and new technologies. Operational excellence means that NCC aims at making function more effective and profitable by strengthening existing expertise, enhancing processes, centralizing purchasing processes and supporting digital information flow.

The thesis uses case company in order to gather experimental data, and because the thesis is limited in the building phase and focusing on individual efficiency and communication, it is unnecessary to interview other than the construction process organization.

The empirical study has two parts: interviews and survey, and then piloting location system and interviewing experience.

3.1 Methodology for interviews and surveys

3.1.1 Interviewing process and a survey

It is not relevant to separate strictly the qualitative and quantitative methods. In the quantitative researches, the percentage values and statistics are used together with qualitative methods in analyzing. These two methods are often applied. (Alasuutari, 1994) This section of the study is intended to chart the people's perception of the communication, waste, and information flow. The objective is not just creating new solutions but along design science research, it is relevant to clarify the real problem and solve it by innovative solutions or enhancing the current methods. As important as finding out what is not working is to clarify which kind of factors are effective and interviews and surveys take account opinion of target group.

This thesis had two methods for gathering information. First, the interviewing process was semi-structured, and then a survey was structured made by Surveypal. These two differ from each other following: in semi-structure interviews questions do not have specific order and form like in structured interview. (Hirsijärvi & Hurme, 1982, p. 36) In the semi-structured interviews, the questions are left as open-ended (Saunders, et al., 2009, p. 343).

A semi-structured interview – also called theme interview – is practical especially when the subject is unconscious. The action can be described as a communication event in which two probably strange people meet and discuss regardless surrounding challenges. The interviewee should be able to rely on the interviewer. (Hirsijärvi & Hurme, 1982, pp. 35-37)

The semi-structured method used in the interview process is non-standardized and each interview is face-to-face individually. In semi-structure interview, the researcher has set of questions and themes. All the interviews are unique and the questions can be dealt with

a different order depending on the course of interview. (Saunders, et al., 2009, pp. 320, 351) This kind of interview method enables to be creative and address a subject when it feels relevant (Hirsijärvi & Hurme, 1982, p. 30). The advantage of this kind of interview is an openness, so that the questions are same for everyone, but the conversation continues with a flow. New and unforeseeable opinions and points might appear. Also, the interviewees could explain their vision with own words. (Saunders, et al., 2009, p. 320)

It is important that respondents have needed information and are willing to share their information. Therefore, the respondents need to understand the aim and the topic of the research. Abstract and difficult words are not suggested, or they need to be defined well. The best way to define the word is to precede a definition in advance, not afterwards because it might question the respondents' intelligence. (Foddy, 2003) Especially along Kalsaas (2010) one problem of interviewing managers and workers about wasted time, is that they have a different conception about waste. According to definition of Haas et al. (2000) the waste was defined as waiting, standing, sitting, early quits and late starts, or any inactive time. Another difficult word might be real-time which means what happens now, and information flow was defined according to Dozzi et AbouRizk (1993) as transferring information.

Marking the interviewees' role is important in quantitative and qualitative researched as they might explain why something occurrences (Alasuutari, 1994). In this thesis, it was relevant to show the roles as they compile groups. The interviewees' names or ages are not presented in the thesis, because they are not relevant and it would prevent their openness. The table 5 presents duties and the date when the interview was made. Several attendances were from the same construction site which enabled to compare responses and to see whether conceptions differ from those of others. The selected interviewees were foremen, site managers, construction managers, and site workers. The bounding criterion was that people are in contact with site employees, because the research is concentrated in the site problems.

Table 5 Interviewees and their duties and interviewing date.

Interviewee	Duty	Date
I1, I2, I3, I4	Foreman	16.10.2017
I5, I6, I7, I8	Foreman	17.10.2017
I9, I10, I11, I12	Foreman	23.10.2017
I13, I14, I15	Site worker	16.10.2017
I16, I17, I18, I19	Site worker	17.10.2017
I20, I21, I22, I23	Site worker	23.10.2017
I24, I25	Site worker	26.10.2017
I26	Responsible foreman	16.10.2017
I27	Construction manager	19.10.2017
I28	Responsible foreman	23.10.2017
I29, I30	Responsible foreman	26.10.2017
I31, I32	Construction manager	27.10.2017

The interview process started with compiling the questions which are based on the existing literature and the previous researches. The interviews handled following themes:

- Time-waste causes
- Communication methods
- Use of digital tools
- Making observations and reporting in real-time
- Information flow

The questions were sent to the interviewees beforehand in order to explore the questions The questions were presented in Finnish and translated in English to the thesis (appendixes 1,2,3).

In the interview, the thesis was presented shortly and then the interviewee told his/her background. The interviewees had different duties, so the answers were expected to differ from each other. The question template afforded a framework for the interviewees but at the end there were subjects which did not appear during the interview and if interviewee had something to add or subjects to talk about more, the conversation continued. The analysis of the interviews is presented in the following chapter.

Another part of empirical study was structured interview by sending a questionnaire for all the foremen and site managers in NCC. A survey is less challenging than interviews as the anonymous is guaranteed. In the survey the answers have alternatives and even they were compiled extensively, they rarely reach interviewees' way of thinking. Anyway, the surveys provide clarifying quite concrete and simple occurrences. (Hirsijärvi & Hurme, 1982) The main empirical method is interviewing, but a survey for wider personnel offers more numerical statistics and according to Hirsijärvi and Hurme (1982) people's roles are not relevant if the goals is to gather information in general. The goal was to get more than 10 % of foremen and site managers to answer during one month.

3.1.2 Analyzing process

The interviews were kept at the NCC office or at the office on a construction site. A phone recorded all the interviews. The answers were transcribed in excel, but not in detailed. The main points were picked up in order to make combinations by themes.

In semi-structures interviews include lot of irrelevant information for the research subject as the interviews might last for a long time if a discussion continues. Because of the large amount of data, the structuring happens after interviewing. (Hirsijärvi & Hurme, 1982, pp. 108-109) The exact clauses were not weighty but the main subjects were gathered. Each interview was charted to see the variety and number of the answers and while handling one theme, some comments of the interviewees were added to explain the answers.

After analyzing the interviews, the surveys were on turn. Surveys provide fast handling process and statistical analysis (Hirsijärvi & Hurme, 1982, p. 29).

3.2 Factors affecting time-waste

The main goal of the interview was to survey which factors cause the most time-waste during a day. The questions were open-ended because according to Polat and Ballard (2004) the open-ended questions do not limit or guide the respondents as there is no standard waste causes. As expected, understanding a concept of waste caused problems. To

explain what is waste, it was defined as activities e.g. waiting, wandering, humping, searching people and materials, so that interviewees understood, what the goal was. The interviewees mentioned more than one factor that cause waste during their day and in general. The results are shown in the figure 4 below.

Figure 4 Factors affecting time-waste according to site workers, foremen, and construction managers and site managers.

According to the Surveypal survey 17.9 % thought that none of the working time is wasted, 57.1 % thought that one hour is wasted and 25 % found that 2 hours are wasted. Respondents at Surveypal were 28.

3.2.1 Foremen

Foremen found that the time is wasted mostly with sub-contractors. Trying to reach and find them and looking after their work take time. The second largest cause was that people are lost and it takes time to find them on the construction site. The third largest cause was time, which is used in searching materials and tools, and the fourth that assignments are not clear and the work cannot progress.

> Per se there is no time to waste but it happens. The subcontractors do not inform, if they are not able to come at appointed time and they always have excuses for being late or not showing up. (I6, 2017).

> But there is a reverse, if the subcontractors were there always and everything passed perfectly, foremen would not have work. Defining the waste is difficult, to know what is quantified as waste. There are lot of work that would belong to the site workers or sub-contractors but anyway the foremen do them themselves while walking on the construction site. (I11, 2017).

3.2.2 Site workers

The site workers found, that searching materials and tools takes the most time by far. The second cause was that assignments are neither clear nor planned well beforehand. The third largest cause was that the place is not ready and the fourth cause is that people spend time with talking with others and wander in general.

> Only few time get wasted when one can plan duties beforehand, but of course searching tools takes times. (I13, 2017)
>
> When one assignment is done, the next duty is not clear. That causes the time-waste, because the foremen do not plan beforehand. (I15, 2017).
>
> The assignment should be planned already, when the next duty starts. In the morning, the briefing is a valuable method to tell what is going to happen. (I24, 2017).
>
> Talking with others on the construction site decreases the productivity, but the humanity is important in this field (I20, 2017).
>
> Gathering the tools and materials before starting a duty and a poor planning takes time. The foremen call and tell to move to another area leading to that all the materials are all around and tasks not finished. The distance between the site and office is large, so walking wastes time. (I22, 2017).

3.2.3 Construction managers and site managers

The construction managers and site managers saw that searching tools and materials, poor planning of assignments and that they do not progress, were the most crucial causes for time-waste. Secondly came the problems with sub-contractors and trying to reconcile new schedules with them, or looking after their work takes times. The third cause was that site workers and foremen wander and spend time chatting with others. The fourth was that the place is not ready to start the work.

> One notable change has happened from the past; foremen do not know what the requirements are for a location before starting a duty. The meetings beforehand, and making check-lists with subcontractors and site workers are neglected. (I27, 2017).
>
> Foremen must spend a lot of time at superintending workers handiwork, and subcontractors especially are wandering a lot on the construction site. Foremen' job is 'putting out the fires'. (I28, 2017).
>
> All the responsibilities of foremen should be clear, to know in which one to concentrate. Going to the site, there are always workers, who ask help, so foremen stay and try to solve it, instead of delegating it to the right person. In the site office, documenting and making reports with different systems take incredibly much times. (I29, 2017).

> One foreman told, that all the waste is caused by poor designing and foremen can never handle their scheduled plans, since there are continuously running affairs that interrupt (I30, 2017).

An interesting fact was that the foremen did not see a problem on starting a duty; they found that the workplace is ready in general. They also did not find that chatting with others belonged to the time-waste. According to the scientific articles and earlier researches, the time-waste is 40-60 % meaning 3.5 to 5 hours a day. That research result surprised many, but some people agreed on the allegation.

3.3 The communication methods

The second theme was concerning the communication methods and tools. The question for foremen was "How do you communicate with colleagues and site workers?" and the results were primarily face to face, so there was no unclarity. Then the question "What is the most remarkably communication method?" divided the interviewees.

67 % of the foremen contacted site workers face-to-face, 17 % called, and 16 % preferred WhatsApp or walkie-talkie. The most remarkable communication tool between foremen whether contacting face-to-face was not included, was WhatsApp or call: 55 % preferred calling and 45 % WhatsApp.

> Depending on who the target of a communication is, the methods of communication vary. Confidence in site workers and subcontractors dictate often, how the situation shall be dealt with. (I1, 2017).

> Everyone should be able to make circumspect decisions and communicate with others. Having a connection face to face or by calling, workers understand their duties, and it provides having a humane connection with others. (I9, 2017).

> Giving instructors via mobile phones is not the right way of managing, instead foremen should go to the site more, because the work is done there (I11, 2017).

> In the construction field, the leading happens on the site, not in the site office, therefore having even workers' numbers is unnecessary. Having only few minutes with workers in the morning can be crucial, then both knows circumstances. (I3, 2017).

WhatsApp is still an unofficial communication tool, but it becomes more frequent despite of users' age or experience. According to the interviews, some construction site teams found WhatsApp groups worthwhile to deliver information in real-time. Even if the foremen wanted to communicate face-to-face, WhatsApp was the most preferred communication tool.

> WhatsApp has a great amount of potential, people can easily send pictures and it should be used globally (I1, 2017).

> WhatsApp is an effective tool to inform visually because a detector can send immediately a picture of the target (I7, 2017).

> WhatsApp is not an official tool and there comes problems such as information security, but it enables attending to matters quickly (I11, 2017).

For the site workers, the relevant question was “How do you contact foremen?” 85 % of the site workers contacted foremen face-to-face on the site office, and the rest, 15 % called. This means, that workers walked from construction site to the site office or searched foremen on the construction site.

> The work is not done alone, so communication and coming along with different people are important. Sending messages to give instructors is not a proper way to be in contact. There is no problem on reaching the managers as they can be found in the office. Calling happens rarely and WhatsApp is not in use. (I13, 2017).
>
> If a foreman calls a worker, who is on the construction site working, and gives instructors about next duty, it gives a vision, that foreman cannot see the whole picture of the process (I18, 2017).
>
> It might be weird to have orders via messages. (I20, 2017).
>
> The company has given a mobile phone for a colleague and WhatsApp enables sending pictures. The foremen do not communicate enough amongst themselves, and quite often they come and ask workers to do one task while another is not completed (I22, 2017).
>
> There is also a reverse, because some prefers to inform and get information quickly by phone. Calling decreases the time used at walking between the construction site and office, but having all the numbers of foremen is needed (I24, 2017).

For the last group, site managers and construction managers, the question was “How do you communicate with foremen?” 60 % called, 40 % used WhatsApp, and 10 % used email. Today, the communication is fast and the information needs to transfer immediately.

> Email is a tool as well, and especially when it is required to have imprint on something, email is the only tool for that (I32, 2017).
>
> An email is practical, because all the involved parties can see the dialogue and take part when needed (I30, 2017).
>
> In a project organization, WhatsApp should have someone who leads, in order that the goals are clear and everyone knows what to put there. It can be a communication tool, but in primary the best and only communication way is talking. (I27, 2017).
>
> The amount of information is so huge, and the wanted facts can get lost in WhatsApp (I28, 2017).

The construction managers required physical contact between foremen and workers. In this field, a humanity forms the basis for good ambiance and working environment. Most of the interviewed managers thought that managing via phone is not a right way to lead

and one common opinion was that morning briefing is essential because few minutes in the morning can reduce mistakes as everyone knows their tasks. A communication with site workers must be continuous meaning everyday contacts and weekly meetings in which the information about the company is shared.

3.4 Digital solutions

According to the survey, all the foremen used a phone on a construction site, and 78.6 % have an Android and the rest have an iOS. The question was "Have digital solutions simplified your work?" According to the survey, the digital tools had simplified the majority at work; only 2 out of 28 people thought otherwise. According to the interviews 67 % agreed, 25 % agreed whether the tools are easy to use, and the rest; 8 % disagreed with that digital tools would have simplified the work. The possible reason for differing numbers between the survey and the interviews is that the foremen, who are not so familiar with digital tools, did not answer the survey because it might have caused difficulties. Today, still the digital tools are not in use effectively according to the question about how foremen or site managers act on a site whether they need to check plans. In the survey, one person could tick many answers. 57.1 % ran to the site office to check plans, the same number downloaded drawings on a device, 46.4 % printed drawings with them, 25 % called someone at the office, and 10.7 % tried to download from internet, but network fails.

> There are many new applications and systems available, but it is substantive to notice what is necessary. The construction does not happen in a stable condition as in a manufacturing industry. This is not taken into account while making new applications and solutions in order to solve problems and simplify processes. (I27, 2017).

> The digitalization has emphasized the work efficiency, but there are also many nice-to-have applications, which only waste time. The applications must have a clear purpose of use. (I30, 2017).

> The observations can be easily done by phone (I32, 2017).

> Couples of years ago, the control lists were made by recording the faults; an older foreman walked through the apartments and recorded the observations. Afterwards he tapped then to the computer, but the problem was that the place was not sure and it caused significantly ineffective time. Additionally, the method resulted in overlaps, and the observation was not visualized or marked on a plan. (I12, 2017).

The managers were more accustomed to technological applications and got an introduction to using them. Otherwise, site workers did not use devices on the construction site: 46 % used phone, 31% used rarely, and 23 % almost never. The work is physical and the devices cannot withstand the dents and the weather conditions. Some found that digital tools enable to run an errand quickly.

> On the construction site, the help will come by shouting (I16, 2017).

> Calling would save time and there would not be a problem to use iPads whether the devices are durable enough (I24, 2017).

Objective is to see which applications are needed and what kinds of solutions only confuse people. The new digital solutions and application may have a reverse phenomenon than planned: the risk is that they replace physical contact and leading. Digital devices cannot replace managers, they can ease the communication, but still managers need to go physically to the site. New applications provide informing about conflicts in real-time.

3.5 The real-time observations

The survey shows a distribution of making real-time observations. 42 % reported either always or usually on the discoveries and the deviations in real-time, 10.7 % reported when they feel up to get phone, and 3.6 % reported nearly never. According to the interviews, foremen always reported on deviations. 64 % sent a message directly to the other foremen, 18 % either called foremen, and 18 % told usually directly to the site workers. As opposed to the site workers of whom 54 % did not inform in real-time; they either waited for a break or to see a foreman, 23 % told immediately someone, and 23 % reported nearly never. The information flow is remarkable between foremen and site workers, and according to interviews the site managers and construction managers are well in the know of what happens on the construction site; only one out 7 thinks otherwise.

Making real time observations may help with several problems. Telling about interruptions and observations require an open and safe atmosphere. The chapter 3.2 presented the causes for time waste and making observations individually could reduce many of them. While telling immediately about the lack of the materials or tools, foremen could procure them as fast as possible, and a site worker could pass to the next duty and get back when the materials or tools are on hand. Otherwise the site worker passes to next duty, goes after a while for a break and tell then for a foreman about the lack and then the foreman starts the procurement. More often foremen send between themselves messages about interruptions or findings, but site workers would like to know in real time about interruptions that resonate with them.

> As one site worker said that even the information flow works, the real-time information is not available. For example when an alimak is broken, it would be nice to know before experiencing it with own eyes from the top floor. (I14, 2017).
>
> Another site worker amplified that observation usually is made whether the action inflects the observer (I23, 2017).
>
> It would help a lot whether observations were possible to make by phone, because otherwise it would not stick in mind (I16, 2017).

The reasons for the low percentage of reporting in real-time about observations were quite similar between interviewees. The site workers would make observations whether the method was simple; now there are notes in the recreation rooms in which they can write their observations and pass them to the foremen. This method is unreliability as people may not remember the observation while going for a break. This method has not anything

to do with a real-time. On the construction site, the site workers prefer to finish their duty and then report for foremen or when a foreman occurs to come by. One challenging and global issue is that all the workers do not have phones on the construction site and actually it has been forbidden till today because of the safety; people lose their perceptual ability while concentrating on phones.

3.6 Information flow

The last theme concerned the information flow. The question was same for everyone: "How well does information pass on the construction site?" The interviewees described the methods of how the information passes and what could be improved to enhance the information flow.

The survey shows a distribution of the methods of how the managers informed the site workers. 92.9 % informed in weekly meetings and 85.7 % in morning briefings, 78.6 % called or told individually, 46.4 % used WhatsApp, 35.7 % stuck fact sheets and notes on the wall, and 10.7 % informed in some other way. Weekly meetings and morning briefings were the most desired from the site workers perspective, but in practice the occurrence of those was low.

Foremen organize meetings with workers and subcontractors, but the problem is to get people motivated to come there. The foremen would like to have an information board in recreation rooms and also on a site in order to inform site workers about e.g. relevant events or deviations. Another problem is that the information does not reach the site workers in real-time. The site managers and construction managers find weekly meetings and morning briefings unconditional to ensure information flow on the construction site. In many construction sites, the foremen do not keep morning briefings which leads to unawareness of forthcoming events.

> Subcontractors are not interested in attending the meetings (I3, 2017).
>
> The workers are not getting the real-time information except by calling (I6, 2017).
>
> Large screens on a site could inform for example for plumbers that the new plans are available now on the site office (I7, 2017).
>
> A weekly meeting for the site workers are significant, but the information is general (I11, 2017).

The site workers thought that they get information when they want it by asking on their own initiative and they do not find that the foremen withhold something from them. According to the interviews, the site workers considered weekly meetings and morning briefings the most remarkable way to be informed.

> Without the morning briefings, it is hard to get enough information (I24, 2017).
>
> The communication plays a major role, it would be good to know for example about lifting, but in general the information flow goes well (I18, 2017).

> In order to get an open environment, foremen need to communicate more (I26, 2017).
>
> What comes to leading, the roles must be clear. The over briefing is malign and thus a chain for sharing information must exist. (I31, 2017).
>
> In the early phase during the framework the information does not transfer enough. In total, the amount of the information is enough and by asking can get more. The morning briefings should be in practice in order to enhance communication. (I22, 2017).

The construction managers also answered to the question whether they give enough information for foremen about the section. None of them thought that they give enough information. The site managers know the importance of weekly meetings with foremen. They found that information flow is not going well. An issue is a mobile work and a never-ending hurry.

> It would be good, that foremen made plans to weekly meetings and respected them, because always appears some excuses not to attend (I29, 2017).
>
> Meetings could be arranged every day, to ensure a sufficient information transmission, otherwise the relevant information do not reach people (I28, 2017).
>
> Weekly meetings are nor respected and site managers should do a preliminary scheduling plan, so that they do not come to the meeting with empty hands (I29, 2017).

One remark from several site workers was that foremen could communicate better with each other and inform about what each site worker does. Some site managers and construction managers think the same way. The foremen should discuss between each other in order to inform in which tasks workers are fastened. The information flow is as remarkable between foremen themselves as between foremen and site workers. A good leading requires communication to be seamless and informing about the relevant matters.

3.7 Summary of interviews and surveys

In principle, none of the interviews was totally unique and differed from the others. All the answers had similar characteristics, but several conflicts occurred. One of the most remarkable conflicts was the concept of how the information flow functions according to the foremen and site workers. The site workers desire to have weekly meetings, morning briefings, and to be more informed regularly. Meanwhile the foremen told that they keep regularly meetings and think that they inform well. At least according to the NCC ERP, the foremen should keep morning briefings and weekly meetings with workers. Some site workers found that they are in the know when they ask independently. In summary, information flow works whether the common rules are kept, and the managers follow the instructions of the ERP. In large picture the site workers find that they get general information enough.

The digitalization has not been adapted still on the construction site due to the complexity and traditional practices. Still some have an old-fashioned mobile phone and people do not use phones on the site. The rate of real-time observations is low, but some workers and managers react immediately. One obvious remark for enhancing the communication is to create a trustful environment and have regular meetings, where all the relevant subjects are shared.

Waste happens for the most part because time is used in trying to find materials and tools and reaching sub-contractors, or work places are unprepared. These could be eliminated by planning the tasks well and respecting the common schedules. Foremen' job is to plan tasks and supervise the job that demand good leadership and management skills. Construction managers pull out fires and should transfer the information between construction site teams. An important remark is that not all waste is supposed to be eliminated; communication (=transferring knowledge) and personal times are included to the working time. The idea is to reduce non-value-added activities in order to increase productivity and also make work more meaningful as no one gains from searching and trying to reach.

3.8 Tracking system

3.8.1 Piloting tracking system by Movenium

All the interviewees answered to the question about what they think of the location system, meaning tracking people. 38 % of the site workers thought it is good idea, the same number thought that it might work well, and 23 % found the system suspicious. 58 % of the foremen found the location system a good idea, 25 % doubted the system and thought that it is not good idea to stalk, and 17 % found the system unnecessary to the construction site. 43 % of the site managers and construction managers found the location system a good idea, 29 % found it is a good idea, but contains risks, and the same number thought that it is unnecessary.

Here the surprising result was that site workers are not that suspicious to be under supervision, whereas the managers scare on the behalf of the site workers. That proves reliability that workers have nothing to hide. Instead, it causes suspects that foremen do not like the idea that they are tracked. One aspect that all the interviewed agreed was that if it was possible in the future that this location system would automatically punch in on a site in order not to use anymore Valtti card[4] to punch in.

According to the interviews, searching people, materials, and tools waste most of the working time. In the surveypal, one question handled on how often foreman tries to find a site worker while going to the construction site. 25 % said "often", 57.14 % said "rarely", and 17.86 % said "never, as I know where the worker is".

[4] *The Act on Occupational Health and Safety require all persons working on a construction site in Finland to have an ID card displayed at all times. The VALTTI smart card gives the worker easy access to the building site as it contains an NFC/RFID chip which can be read by the construction site access system.* (Tilaajavastuu, 2018)

This thesis concentrates in time-waste caused by communication problems, so the location system would hasten finding people and tell if workers are where was planned. There are different technological solutions. This thesis piloted the location system in NCC construction site in Laajasalo in which erection by elements of one block was done. The piloting was made with Beacons and an application. Beacons were placed on the construction site and then an application on a mobile phone functioned as an identification. The positioning system has two applications needed, a Visma Entry Tracker that functions as a detector and the Movenium application as a tool showing on timeline where a person is. The Movenium application works with a computer and on a mobile phone which is necessary so that worker and foreman can see quickly where the person is. The Visma Entry Tracker is connected to the Beacons that are installed on the construction site. They are connected via Bluetooth, and the Beacons send the real-time position to the site URL. Analyzing the data in detailed level is not purpose in this thesis.

During this research, the piloting did not give the wanted results because of the technical problems. This thesis did not survey the labor productivity but the objective was to hasten finding people. The used application had many difficulties in the software but also the construction site environment caused problems. The first adversity was to get a permission for tracking. The purpose was described well; to hasten searching people, to enhance productivity, and in the future possibility to automated stamp. In addition, it was highlighted that in this research purpose was not to spy people in micro level and the gathered information is not used in payroll computation. The contract was clear but people doubted the purpose and felt uncomfortable to be spied. The goal and the purpose were defined as detailed as people wanted and they could abandon the contract whenever they want. Anyway, six people, including foremen and workers, gave a permission on the piloted construction site that presented almost half of the employees.

In practice, a worker and a foreman must put the Bluetooth on while going to the site. After having downloaded the Visma Entry Tracker, user does not need to touch the application anymore. The tracker is on when a person is near a Beacon, and time starts running on the screen. The system burns out 1 % battery of mobile phone in one hour, which mean during a working day 8 %.

The goal is that while going to the construction site, a worker and foreman can check quickly the location. The location tells which Beacon is the nearest. In the application, each Beacon is presented in different color and they can be named as wanted. In this research, only seven Beacons were in use; five of them were placed in each floor, one on the construction site entrance, and one on the storage. The figure 5 shows the outlook of the Movenium application. Each worker and foreman will be added to the system adding the IMEI of the phone, which works as an identity and then, the initials represent the person in the application, such as here RS means Roosa Selkämaa.

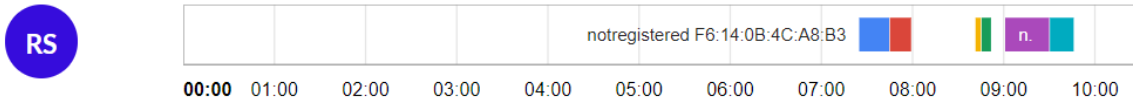

Figure 5 Beacons send the location via Bluetooth; each color represents one Beacon.

After placing the beacons, they needed to be named but because of the connection problems, the Beacons and mobile phones did not interconnect. The naming process was impossible, as the identification of a Beacon failed. Beacons were working while testing them on the office, but concrete elements block the connection on site condition. The beacon outdoor was the only one working. The construction site had a base station but it was not enough, there probably should have been several.

The next adversity was the functionality of the application because it worked only on Android, and not even on all models. That erased more than half users because today most of the foremen and workers have iOS, and some have not even a smart phone. The other problem regarding mobile phones was that especially site workers keep their phones in the social facilities to avoid them to get broken. The presumption of today situation that everyone has a mobile phone on the construction site is not relevant.

3.8.2 Interview of experience

Aalto University is making a research about tracking people and their purpose is to analyze the time use. Their system is called iCons (Intelligent Construction Site). They are piloting tracking system in some construction projects and for this thesis it was relevant to interview about the experience of one tracking project. Additionally to that, the Movenium was interviewed about developing their system.

For his thesis, a Doctoral student Jianyu Zhao was interviewed about his doctoral thesis. In the piloting, they have beacons which people carry on and gateways are placed in the building. The gateways send the information to the cloud service when the beacon and the gateway have been in contact. The data shows duration and a place where employee is located.

> *We report this kind of time stamp information of localization which is a gateway number to a cloud service so they store every role they have in there and after days and months we download extract data of everyday we want and my job is to also do a data analysis or interpret the behaviors of the workers that includes non-value adding time.* (Zhao, 2018)

An objective of analyzing the data is to compare the schedules and actual working time (Zhao, 2018). The quality of work is not possible to measure only with tracking and making conclusions needs lot of analyzing data. The location system data shows inactive working time, but analyzing process is challenging. The amount of the data is huge and

analyzing means that you need to make lot of assumptions such as whether the time is inactive if the worker is not in the workplace.

> *I think the hard part is […] how to identify the behaviors of workers from the row data because I think for this approach also it tells when you see a fraction, you can only see a time stamp and location.* (Zhao, 2018).

Each beacon or gateway (depending on which is placed on a construction site) need to be identified and named as wanted so that in the data extract it shows where employee is. The strategy for placing the gateways or beacons is considerable as they might resonate with each other. A worker might be in the middle of all the gateways and that does not give a reliable information about position. Another problem is that indoor the construction site the connection is not guaranteed so before piloting the connection of gateways must work.

As the Movenium application was not working during the thesis, the research and development manager of Movenium, Pekka Kinnunen told how the system is going to be developed.

> It is clear that technology of piloted system was in its infancy; in nowadays systems mobile phones one time function and another time does not, and additionally the situation in which each room has own base station is way too expensive. Companies should buy to each base station a SIM card or get wireless connection with a cable which is not possible before indoor work. Now Movenium is developing the system with aid of one base station to which each Beacon is connected. Beacons are sending the information to the base station and then the base station sends information to the cloud. (Kinnunen, 2018).

In conclusion, the system needs a development. To solve connection problems, solutions are expensive regarding internet connection and that mobile phones are not mandatories on the construction site.

4 Solution proposals for case company

Similar subjects and issues appeared in the literature, earlier researches, and interviews. In this chapter, the solution proposals are based on the items which appeared in the empirical study and then validated by way of the literature.

The main problems for time-waste and poor information sharing are caused by communication issues, a divergent concept of the current situation concerning how information should be shared, poor connection on construction site, and the technological challenges. Common rules and coherent methods will improve attitudes towards the technology development. Implementation of the technology is inevitable. Next, the possible solutions that have an influence in the effectiveness of the building production phase are presented. One significant remark is that the resources for the solution proposals already exist but they have not been in use.

4.1 Systematic communication

According to the interviews, the weekly meeting for the site managers and site workers need to put in the operation systematically. Site workers like to have morning briefings and to be more informed regularly. At NCC's ERP there are common rules on how should act, but many still go against the stream. The reason why these meeting and briefings are not kept regularly is hurry. Even the hurry exists; always there seem to be time for looking cars in the website or chatting on phones.

Some responsible site managers would require summarizing actions of the day with site managers, because it has had positive impacts. The meetings are not there for the principle reasons; they have a purpose, so the site manager and construction managers need to recognize whether they are necessary.

The meetings always demand someone to lead the course. The subjects to be handled in weekly meetings between foremen and site managers are unclear. One common template that shows subjects that need to be discussed should exist in the ERP. Especially when the project team changes a lot, the information does not find as far as wanted. The template of subjects to be considered conducts also the new employees. All the projects are unique, and the content of the templates need to be modified depending on the subjects. The meetings and informing about modifications and news create an atmosphere, in which the managers show that they know what is happening and also construct confidence.

4.2 Better planning

According to the results of what causes most time waste, planning seemed to be one of the major reason for that. Planning contains task planning and preparing the locations. While the location is not ready or assignments not clear, workers have to wait and that increases ineffective time meaning waste. Quite often workers felt that foremen call them and ask to do another task even they have one task unfinished. Foremen should communicate and inform about current situations more, and for that a shared network is required in order that each member has access to modify and check the plans.

As came up in the literature review planning the task does not get enough time. All the members who are involved in a project, should be involved also in planning the tasks and scheduling. Last Planner was presented in the chapter 2.6. as it provides task planning at phase and reduces making overlaps. A common board improves the co-operation between site management because the construction team changes and cultures and educations differ which lead to challenging communication culture. That came up also in the interviews.

NCC has in the Office 365 an application called Planner. Along its name, it is based on the Last Planner, but the redeeming feature is usability by a digital device. A foreman adds a task, defines a person in charge, a starting date and a closing day, and additionally can attach a checklist and comments. After having created the task, the progress must be defined: either 'not started', 'unfinished', or 'finished'. The figure 6 presents the process of adding a task. All the members can add themselves to the Planner, so that the tasks are shown for everyone. This tool requires also settling the task after finishing it. The shared tabloid could show the degree of preparedness automatically, when people in charge updates the state of the tasks. The idea of the Last Planner is to define dependencies so that tasks are prepared in advance. To recognize dependencies, the eight waste "making-do" would be eliminated as the task would not start before all the requirements.

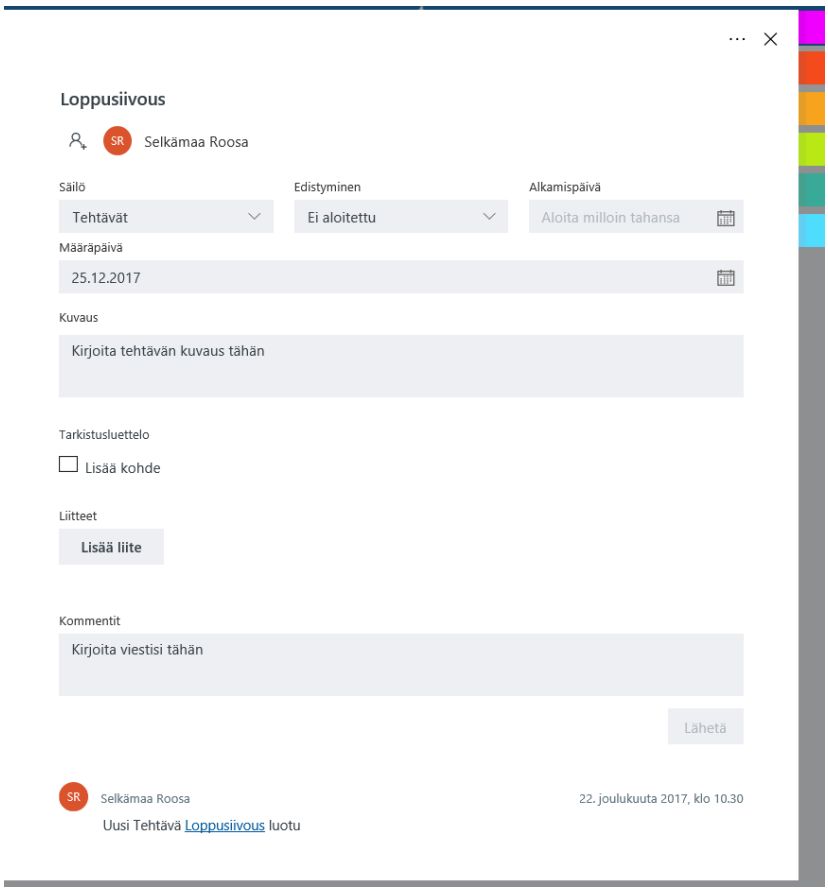

Figure 6 A Planner tool for controlling the production.

4.3 Documenting flaws and reacting in real-time

According to the literature, the flaws documenting presented in the chapter 2.4 – why, when, where, who, and how – provides to understand why the waste happens and also

enlarge the concept of what the waste even is. The real-time tools ensure the safety. The construction sites have zero damage goal, and the real-time application help to achieve that, but do not replace the safety practices on a site. (Teizer, et al., 2010)

According to the interview and survey, making real-time observations is not platitude. A global problem is that workers do not use mobile phones on a construction site. But that is understandable because in the construction field, a phone easily gets broken whether it drops or dust spoils it, but also people lose their focus on surrounding environment that affects safety. Mobile phones are forbidden according to the safety regulation, so either worker or foremen follow the safety rules or they use phones to enhance production. Foremen use phones, but still according to the survey, less than half of the respondents inform about deviations. Tools that are in use are WhatsApp or telling face-to-face.

According to the literature and interviews, people call or walk to the site office. Again one problem appears: all the phone numbers are not available. In the access control system, all the new members could give their IMEI, and messages could be sent via wireless connection to the person. A simpler way is to give a phone number, and foremen could send a message with a wireless connection to the person whose number is available in the access control system. Workers, foremen, and sub-contractors spend significantly time searching numbers, and calling is not the most functioning way whether the person is not answering, the number is lost, or the connection fails.

Several applications for communication and making observations exist and at worst, people must have them all. Now on a construction site NCC has in operation one application to communicate with other foremen, another to make real-time observation, and the third to report about safety observations. All these tools should support actions on a construction site, but often the information gets lost and does not even reach an interested party. The objective is that the construction site team could profit from the observations. Today, NCC uses for safety observations a Synergi application, but here comes up the main issue: the observation goes forward but is not passed on the construction team who could correct it. In addition to make an observation, which is shown on a company report, the person must forward the observation to the interested parties. This wastes automatically time as the work is done twice.

According to the interviews and survey, WhatsApp develops continuously and regarding the communication, in the group chats one message can be targeted at certain person adding @ before the name of the person. The person will get a notification to that message. This characteristic solves two considerable problems: the responsible is designated and time used in trying to find wanted message decreases. Defining the responsible is indispensable to avoid that “someone handles”. The famous “someone” must be eliminated from the projects and a person in charge defined.

Another continuous problem is that the location of the devastation is not defined. Taking a picture on a construction site and sending it to other requires writing by hand the location. Sometimes it might be difficult how to define a location and how detailed, but here the visualization is significant. It is enough to send a location with a room accuracy but then flag the location with a tape or spray.

Sujuva is an application that is targeted to the workers on a construction site. The goal is to locate deviation, a reason why the task is interrupted, and to direct it to the person in charge. With the application, the wasted time is measured which means that the timing is on between sending the message and after correcting the devastation. This kind of application has potential on the construction site according to the discussion of interviews when I asked what people think about it. Some said that it has too many steps, and a faster way is to call, but some though it would be a good tool. The potential feature is that the application enables sending picture, requires a person in charge, locates the devastation, and shows how much time in general reacting takes.

As a user, making observations via the application is a multiphase process. On a construction site, for workers and foremen the goal is to get help fast, pass to the next task, and get connection without walking to the site office. The application will be downloaded on a mobile phone but today it is a testing application. At first an employee must choose the construction site, on which the application is in use. Then the category of the interruption is chosen and then the location is defined precisely. One step is a need of help; either “an immediate help”, “before the working area is ready”, or “NCC takes care”. Then the person must describe the reason of the flaw with a picture. Next the receiver is chosen and the notice is sent. The time starts when the notification is sent and after the flaw will be handled, the observation maker must close the notification. The figure 7 presents the process.

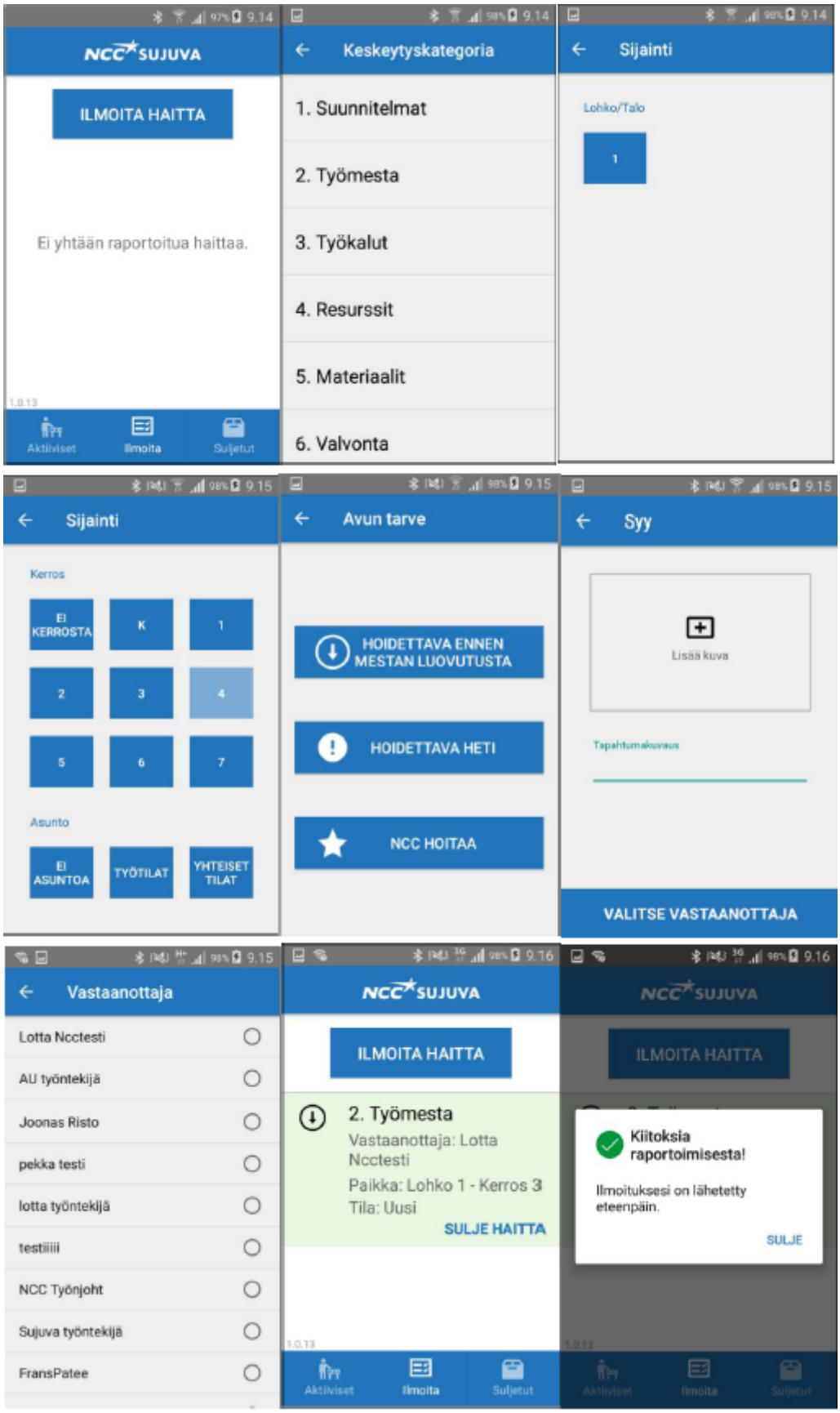

Figure 7 The process of Sujuva application for making real-time observations.

Sujuva has been in use on some construction sites, but people have not adapted it because they prefer to call. The gathered data from one construction site is attached to the thesis.

Data sheet provides to see the most marked category and to gather information about the reasons. The working area (Työmesta) causes the most interrupts which came up in the interviews as well. According to the data, 68 % of the deviations are linked to the working area. The most current reason for the interrupts is lack of cleaning or unnecessary objects are located in the working area.

To make changes and see which factors cause interrupts, analyzing the data is essential. Timekeeping and choosing the category are not relevant from the view of the observation maker but concerning the analyze those are significant particulars. The information enables to see an entirety and repeated factors. The data should be available for everyone, so that the repeated interrupts can be eliminated.

The first adversity was the use of mobile phones on a construction site. When someone needs to download something on an own mobile phone, it divides people in a half. People are suspicious about information security but also that some application uses a great amount of battery. The application still has problems, as the observation maker forgets to stop the clock, even the deviation has been fixed. This gives a misrepresented information of the situation. The best feature of the application is the picture and the person who is in charge.

4.4 Use of tracking system

Additionally to time used in searching materials and tools, searching people consumes foremen's time. Location system provides real-time information about the current status on a site but also in a large picture it affords seeing people's time use which is useful to analyze effectivity of workers and their time-use. Nevertheless as Zhao explained analyzing the data requires a substantial amount of time so in order to analyze each worker's effectivity, many analysts need to immerse in the subject. According to the interviewees, the need of tracking divided people but one feature of tracking got a good reception: automated stamping in. Even the tracking system would not be used in order to study effectivity on a site, it would reduce oblivion of stamping the Valtti card which is mandatory. That will be developed by the companies that are making the application.

The location system is practical in order to see quickly whether an employee is at workplace and how much time is used at storage or in social facilities, and also in high buildings because of the safety. It fastens finding people and an essential occurrence that came up also in the literature is saving the data. Even worker's effectivity is not studied from the point of view of the quality, the working time that is used at one task is useful in the coming projects. The tracking has lot of potential but the benefits on a construction site need to be defined well before putting the system in operation.

5 Conclusion and suggestions for further research

5.1 Reaching the objectives of this study

At the beginning of this thesis, the research questions were defined. This chapter answers to those questions by combining the results of literature review and empirical study.

The main research question was:

> How could time-waste be reduced by solving communication problems in a construction project?

And the sub questions were:

> Which kind of factors affect one worker's effectivity?
>
> What is the role of communication as a factor in time waste?
>
> How the digital tools support communication?

The main research question will be assessed last.

5.1.1 Factors that affect a worker's effectivity

As the main problem concerning the productivity in the construction industry is the huge amount of non-value-added work, the focus must then be on finding the causes for that. Productivity is possible to measure at macro- or micro-level of which the latter focuses on workers' time use and effectivity. According to the literature and interviews, many similar phenomena appeared. It is incredible that the researches made in the 1990's look-alike the researches made in the 2000's. That means that in the industry the knowledge of the situation is not reached the construction organization or the reasons are tried to find from somewhere else than from a site.

At micro-level looking at one worker's time use and effectivity, following factors appeared in both parts of the thesis: ineffective site management, poor planning, lack of information, unknowing to use digital tools, and unawareness of location of materials and people. Most of the sources are controllable such as improving the working methods and concentrating on production process have a significant affect, as can be seen in the manufacturing industry. Anyhow, the construction industry has lot of potential and resources to enhance the production but seems that the ways to do that exist only in theory.

According to the literature too often unmotivated or unskilled workers are blamed for low labor performance when ineffective site management is one of the major reasons. Site management needs to offer a safe working environment, support, and motivate workers. Unmotivated worker does not work as effectively as a worker who has safe and healthy condition. Motivation and productivity are dependent on each other as while motivation increases, productivity increases and the other way around.

Even the construction field is old-fashioned and people assume several things, the communication methods should be established. The weekly meetings for the foremen and

morning briefins for the site workers should be arranged in the operation systematically, because their role is not only managing task but lead teams and people.

According to literature, planning is one of the main responsibilities of the management. Poor planning leads to misunderstandings and misinterpretations, and is one of the major reason for reworking. The problem is not new as Kalsaas has identified 2004 "making-do" regarding poor planning as one type of waste. Planning should ensure the conditions for the task in terms of resources and location. Site management does not have to figure out the resources which are required for a task, in Finland Ratu-database affords the information about circumstances, costs, schedules, quality, and safety.

As Lean construction has existed for few decades, the tools have been developed but they are not implemented as in the manufacturing industry. The most significant tool for planning is Last Planner which affords project control as the tasks are planned at phased. All the stakeholders need to be involved in the planning process, as a building project rests on the communication between all the parties. On a construction site, there are no standardized system to follow and looking at NCC's ERP Last Planner exist but it is not in use. The lack of knowledge what needs to be done impairs the whole process.

Interviews showed the same appearance than literature that communication might be challenging between the site managers as the team changes many times during the project. In the site office, the schedule must be shown in order to let everyone know about the main activities and milestones during the week. One existing problem according to the interviews was that a great amount of information gets lost. That is not surprising, as people are mobile in unstable environment and handle job affairs verbally. In addition to verbal leading, the visual leading supports communication culture especially when people do not have a common language.

Another problem concerning the communication on a site is lack of informing in real-time. Real-time information provides reacting immediately in order to eliminate the waste at early phase, because reworking is one of the main waste causes and it affects workers' motivation. According to the literature and interviews, people often transfer the information only if it touches their work. This leads instantly to the situation in which someone else will be affected by the effects of withholding the information.

To condense which kind of factors affect one worker's effectivity depend a lot of site management and their performance including focusing on reacting in real-time and ensure that needed information is transferred to the parties. From workers perspective, motivation, safe environment, and preconditions without unnecessary actions such as finding materials and tools, waiting for location to be ready, and poor instructions ensure that each worker could use their time at value-adding activities.

5.1.2 The concept of time-waste

The concept of waste is according to literature and interviews unclear. Waste is understood as a material waste and other concrete that is possible to eliminate by throwing away. It does not stand to reason that the word "waste" contains time waste including actions that are ineffective and unnecessary.

According to the literature, the same waste causes – poor planning and communication – have existed since 1990's. It is unfortunate that the same activities repeat and repeat constantly in construction industry whereas the other industries find solutions and modify them regarding their needs.

A time-waste alone is not directly reason for low productivity on the construction industry but is more a consequence of poor planning or extra work. The working time usually is shared to the direct work, supportive work, and delay meaning time-waste. To combine results of the interviews and the literature, the time-waste means waiting, wandering, late starts and early quits, personal breaks, searching materials, tools and people, and trying to get hold on sub-contractors. The effects of these activities are shown on the budget and on delaying, but also the confidence between the parties is affected. Even the actions are smaller and might seem to be irrelevant concerning time waste – e.g. late starts and early quits – they accumulate in large amount a significant part of wasted time.

The waste amount according to the literature is in contravention of results from the interviews as interviewees did not agree that around 30-40 % of working time is ineffective. As came up in the interviews and surveys, people do not find that any of time is wasted. That shows that the concept of waste is not adopted and probably there is no knowledge which kind of action bring value to the project. All the waste is impossible to reduce because personal times and breaks belong to the day but all the other actions that are just consuming time but not bringing any value are waste.

In order to enhance the production, the focus must be on the actions on a site and the waste which happens in real time. It is too late to start looking what went wrong after weeks. According to lean theory, the waste should be eliminated and rework should not exist. This is the reason why reacting in real-time plays a significant role in eliminating time waste and also other types of waste because the point is to prevent waste from developing.

There is no fast way to measure time-waste as measuring time requires lot of analysis, case studies, researchers, and also assumptions. To make conclusions, the time use need to be surveyed by many researchers for long periods. It is quite clear that time waste will happen on a site as the conditions are not like in the manufactures but an essential part of time-waste can be reduced by enhancing the current methods.

5.2 The role of communication as a factor in time waste

The communication affects how well the information is transferred on a site and between different sites. Especially communication between sites should be more transparent as the problems are never unique, same mistakes occur on the other projects as well. Traditionally knowledge passes verbally on a construction site but documenting provides learning also in the further projects and in the other projects. In the construction industry where the project environment is constantly changing nothing will improve if the information is hidden as someone would learn for someone else's mistakes.

The answer to the questions what is the role of communication as a time-waste is essential. Actually the lack of good communication and information flow are the reasons why

time is wasted on a site. Even if the communication is considered important and necessary, the communication methods are not clear. The communication methods tell a lot about managers and their skills. As a manager the role is to know how to communicate and lead people and take account of workers individually because some of them may not like if they are getting instructions by message.

The current opinion of the information flow differs between site managers and site workers. Construction managers do not think they pass enough information forward, foremen think they pass enough, and site workers are content about the current situation but hope more information regularly. The most desired ways to inform are morning briefings and weekly meetings which both appeared in the literature and interviews. Even they are mandatory according to the ERP, many site teams dismiss them.

A hierarchical organization might sound old-fashioned but in large companies it is a prerequisite in order to avoid briefing over others. Everyone should know who is the person to contact depending on the matter. In construction companies, the line organization works so that foremen give tasks to the workers, and site managers give instructors to foremen. The amount of information may be unending and the managers must recognize the relevant information to tell because informing about irrelevant things wastes the active working time, and as appeared in the interviews, meetings should have a clear objectives not just talking.

A reliable and safe environment affords everyone to talk and without telling about schedules and happenings, many interrupts happen. Already following the common practices makes difference. The continuous intercourse means that everyone respects the planned meetings, do not use hurry as an excuse, use a shared scheduling system, and encourage the younger and more silent ones to talk. In short the importance of communication can be described as following: an effective communication provides strong interactions and ensures transferring enough information in order to learn constantly now and in the future.

5.3 The digital tools support communication

There are no one answer to the question about how digital tools support communication but many aspects. The digital devices provide transferring the news, changes, and modifications in real-time to all the parties in order to learn in the future projects as well. Nevertheless the digital tools cannot replace management, and according to the interviews some are afraid that foremen will not go to the site but contact workers only from the office.

According to the interviews, the digitalization has improved the working efficiency, but has also challenges. The most substantial challenges are connection problems and use of devices on the construction due to lack of technical know-how or the complexity. Technology culture is familiar already in the other industries, but the construction site environment still needs to catch up the development.

Companies compete on creating effective applications for several purposes of use. Already there are dozen different applications from several companies with the same objec-

tive but the usability varies. In the interviews, that occurrence of using several applications came out, and it was taken negatively. It is relevant to ask why a common network and easy access to information are spoken constantly but in contrast the information has been separated to dozens of different applications and networks that do not interconnect. An optimistic situation would be that the different communication devices and applications would interconnect. Always before implementation a new application into practice, it is relevant to ask who is the target group and if it facilitates the work.

The most used communication tool in addition to face to face is WhatsApp, even that it is not an official tool. Using unofficial applications are risky because of the security and they are not in connection with the company's ERP. The features of the WhatsApp support the communication between project members, as it contains the visualization, group chats, and immediate communication. The pictures can be sent easily, the message goes directly to the wanted person, and the application does not cost for a company. Anyway, thinking of learning and documenting, WhatsApp does not leave a mark behind so it should be used in order to handle and communicate about subjects that do not need to be saved anywhere. Also everyone does not use phone or WhatsApp during a working day, especially site workers do not want to risk that to own phone breaks. The low usage of mobile phones is global and not simple to solve as the solutions and phones are expensive.

Even if in their strategies many companies have digitalization and technology as items, companies are not realizing it by putting resources, especially money, to take remarkable steps toward high digitalization level. Investing has many targets e.g.: buy phone for everyone, train people to use devices, solve connection problems by buying base stations, and implement real-time applications. The results of high digitalization have been noticed but they still are slowly adapted. One example that is relevant today in which investments are still small are location-based systems. The systems are right ones to attack the relevant problems about lack of real-time information and time-use on a site.

The location-based systems are not popular according to the literature and interview due to many facts: connection problems, costs, and people's attitude. The location system has several goals e.g. reduces time and costs, locates people, analyses the time use. The technology affords a base for the system as the information is sent to the cloud. Now the location systems rely on RFID, beacons, and gateaways of which the benefit is that the user do not need to do or show anything but is identified automatically. From worker's perspective, this location system has potential if it replaced stamping. In the future the location system would recognize the user automatically.

If the goal of using the location system is to define effectivity and study the time use, the analyzing process is laborious. As seen in the doctoral thesis of Shao, the analyzing process requires lot of conjectures and time in analyzing. In realistic the data is huge and it should be analyzed constantly. Depending on how much data people want to analyze, it must be chosen how often the gateways or beacons send the location information to the cloud. Analyzing thousands of rows of the data in micro level on a construction site takes lot of time so it is at least now impossible as the time is already in short supply.

If an analyst wants to know in very detailed level on what time is used, the assumptions might affect worker's feelings. One of the most significant result of the thesis was that workers are not against the location system but site managers, construction managers, and foremen have doubts especially on workers' behalf. This occurrence from the empirical part shows that workers are willing to enhance the production and are loyal.

To conclude: digital devices and solutions enhance communication and connect people as they provide reacting in real-time. Nevertheless, the communication problems are not able to be fixed by tools and devices. In order to benefit of technology advantages, the organization needs to train and put resources so that they become part of everyday operations.

5.4 Reducing time-waste by solving communication problems

For the main research question "how could time-waste be reduced by solving communication problems in a construction project?" exist several possible solutions which create together an effective combination. First of all, communication must be understood as transferring information and recognize the possible communication methods. When looking at causes for time-waste, communication does not appear alone because many factors and activities are actually type of communication e.g. planning, leading, having meetings, training.

According to the design science research, one should first recognize and understand the root reason for communication problem and only after that start the process to improve it. The benefits of eliminating non-value adding activities and making even small improvements might be challenging to see during the project so it is relevant to clear what the project will achieve. Construction companies should talk about effectivity of a construction site in order to spread the situation and possible improving methods. Time waste is challenging to see and recognize as many have different concept of its contents. Today the tools which support communication exist but there is no enough effort and resources on putting them in operation. Positive side is that today many companies see digitalization as a part of strategy, so the importance is growing. Being part of the strategy is a good base for developing the systems.

5.5 Reliability and validity of the research

The literature review was based on relevant scientific articles and researches. It was challenging to find researches which concern communication problems on construction site but communication was linked to the researches concerning time waste. The studies about time waste require lot of time so there are no many researches about it, and to this thesis some of the used references were from 1990's. Nevertheless, the methods and actually results were similar to the studies from 2000's.

The target number of responds in the Surveypal was 10 % and that was exceeded; 43 saw the survey and 28 answered. The Surveypal answers supported well the interview answers. The interviews were quite long and people understood the concept of waste in

different ways, which as for affect in results. The composition of questions was significant as the objective was to get personal opinions of the current situation. In this research only NCC's own workers were interviewed so it might have been affected the answers.

5.6 Proposals for further development

In this research, the objective was not to study productivity which is anyway connected to the time use. Although time use does not show the quality of work, it should be studied even the analyzing process demands lot of work. The data of movements are not clear and making assumptions and guesses are unavoidable. Till now the data gives the information about the location and time.

In the future, the quality of work could be studied. When real-time tracking system works well and the incoming data is tolerable, the amount of movements and non-value-added activities could be studied. The movements are for example results of unorganized working place. The study could also contain how planning affects productivity as in this thesis it came up that leading methods affect but the leading methods were not studied more. The productivity cannot be studied only on one construction site, to make conclusions, enough data must be gathered from several construction sites. Especially the different working methods between workers who are paid by hourly wages and workers who are paid by the piece should be studied.

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I3, 2017. *Site manager* [Interview] (16 October 2017).

I4, 2017. *Site manager trainee* [Interview] (16 October 2017).

I5, 2017. *Site manager* [Interview] (17 October 2017).

I6, 2017. *Site manager* [Interview] (17 October 2017).

I7, 2017. *SIte manager* [Interview] (17 October 2017).

I8, 2017. *SIte manager trainee* [Interview] (17 October 2017).

I9, 2017. *Site manager* [Interview] (23 October 2017).

I10, 2017. *Site manager trainee* [Interview] (23 October 2017).

I11, 2017. *Site manager* [Interview] (23 October 2017).

I12, 2017. *Site manager* [Interview] (22 October 2017).

I13, 2017. *Site worker* [Interview] (16 October 2017).

I14, 2017. *Site worker* [Interview] (16 October 2017).

I15, 2017. *Site worker* [Interview] (16 October 2017).

I16, 2017. *Site worker* [Interview] (17 October 2017).

I17, 2017. *Site worker* [Interview] (17 October 2017).

I18, 2017. *Site worker* [Interview] (17 October 2017).

I19, 2017. *Site worker* [Interview] (17 October 2017).

I20, 2017. *Site worker* [Interview] (23 October 2017).

I21, 2017. *Site worker* [Interview] (23 October 2017).

I22, 2017. *Site worker* [Interview] (23 October 2017).

I23, 2017. *Site worker* [Interview] (23 October 2017).

I24, 2017. *Site worker* [Interview] (26 October 2017).

I25, 2017. *Site worker* [Interview] (26 October 2017).

I26, 2017. *Responsible site manager* [Interview] (16 October 2017).

I27, 2017. *Construction manager* [Interview] (20 October 2017).

I28, 2017. *Responsible site manager* [Interview] (23 October 2017).

I29, 2017. *Responsible site manager* [Interview] (26 October 2017).

I30, 2017. *Responsible site manager* [Interview] (26 October 2017).

I31, 2017. *Construction manager* [Interview] (27 Ocotober 2017).

I32, 2017. *Construction manager* [Interview] (27 October 2017).

6 List of appendixes

Appendix 1 Interview questions for foremen

Appendix 2 Interview questions for site workers

Appendix 3 Interview questions for site managers and construction managers

Appendix 4 The information of reaction time of Sujuva

Appendix 1 Interview questions for foremen

Background:

Presentation of the research

Interviewee's name, role on the site, age, and experience on the construction site

Charting which operating system mobile phone has

Questions:

What causes the most time-waste during a working day (waiting, searching materials or workers, etc.)?

How do you communicate with colleagues and site workers?

Have you noticed that one communication method is overwhelming?

Have digital devices helped your work and do you keep pace with digitalization?

Do you inform about deviations and waste in real-time to your colleagues or other ones working on the site?

How well does information go around on a construction site and in the office?

What do you think about location system?

Appendix 2 Interview questions for site workers

Background:

Presentation of the research

Interviewee's name, role on the site, age, and experience on the construction site

Charting which operating system mobile phone has

Questions:

What causes the most time-waste during a working day (waiting, searching materials or workers, etc.)?

How do you communicate with colleagues and site workers?

Have you noticed that one communication method is overwhelming?

Have digital devices helped your work and do you keep pace with digitalization?

Do you inform about deviations and waste in real-time to your colleagues or other ones working on the site?

How well does information go around on a construction site and in the office?

What do you think about location system?

Appendix 3 Interview questions for site managers and construction managers

Background:

Presentation of the research

Interviewee's name, role on the site, age, and experience on the construction site

Charting which operating system mobile phone has

Questions:

What causes the most time-waste on a construction site?

How do you communicate and how with colleagues and site workers?

Have you noticed that one communication method is overwhelming?

Have digital devices helped your work and do you keep pace with digitalization?

How well-informed are you about actions on a construction site?

How well does information go around on a construction site and in the office?

What should be improved regarding communication?

What do you think about location system?

Appendix 4 The information of reaction time of Sujuva

from_id (S)	time_stamp (N)	time_stamp (N)	building (S)	category (S)	floor (S)	incident_id (S)	location_id (S)
Rein Rand	1,49389E+12	4.5.2017 9:25	A	5. Materiaalit	5	e73f0e8f-ccf1-ccac-1eb2-f194e7a6e8e6	Martinlaakso
Rein Rand	1,4938E+12	3.5.2017 8:34	A	5. Materiaalit	6	e4ec7a08-9c2d-5bad-1dbb-9c197861876a	Martinlaakso
Rein Rand	1,4918E+12	10.4.2017 6:11	A	2. Työmesta	5	3f03a77f-aa9b-7b58-6841-5642eac2d6bd	Martinlaakso
Aleksi Eerola	1,49145E+12	6.4.2017 4:35	C	2. Työmesta	0	94f95b1d-72e9-8eb1-f61b-1f8ade4c9d4f	Martinlaakso
Aleksi Eerola	1,49145E+12	6.4.2017 4:34	B	2. Työmesta	6	2f6a7240-f3dc-cc6d-e079-7a58a08cc5d4	Martinlaakso
kristo männik	1,4913E+12	4.4.2017 11:04	B	5. Materiaalit	7	13290d45-31d7-9856-dada-67f06132f65b	Martinlaakso
kristo männik	1,49095E+12	31.3.2017 9:59	B	2. Työmesta	2	87ebd4ef-c189-9ddc-800d-a052038ec20b	Martinlaakso
Tuomo Pikkusilta	1,49095E+12	31.3.2017 9:55	A	2. Työmesta	8	74e28073-b7dd-dd00-e948-aeb568474cdc	Martinlaakso
Jari matilainena	1,49095E+12	31.3.2017 9:48	A	2. Työmesta	8	35fd8845-dcec-24cc-81c9-04a4a299afb2	Martinlaakso
Tuomo Pikkusilta	1,49095E+12	31.3.2017 9:45	A	2. Työmesta	8	209b9804-80dc-f6c1-342e-62777ff48d0b	Martinlaakso
Sami Ilonen	1,49094E+12	31.3.2017 6:17	B	5. Materiaalit	7	4f49c002-1651-24f2-d6ca-4a18698e74c6	Martinlaakso
Rein Rand	1,49087E+12	30.3.2017 10:25	B	5. Materiaalit	3	0175219e-b7e0-9f3b-3cf6-4c56f165fcaa	Martinlaakso
Rein Rand	1,49086E+12	30.3.2017 7:48	B	2. Työmesta	2	f9f05057-ca86-fb87-78c0-857942eb0cb0	Martinlaakso
Jari matilainena	1,49086E+12	30.3.2017 6:37	A	2. Työmesta	8	90685cfc-6c87-bbb4-9286-80a62494580a	Martinlaakso
Sami Ilonen	1,49085E+12	30.3.2017 5:03	C	2. Työmesta	6	2664e8ab-dfe7-2288-ac04-9ed940f648d8	Martinlaakso
Aleksi Eerola	1,49085E+12	30.3.2017 4:31	B	2. Työmesta	6	959b4aba-afd3-104e-4671-60c75f43388a	Martinlaakso
Jari matilainena	1,49079E+12	29.3.2017 11:16	A	5. Materiaalit	7	3f1bef1f-4d3f-7237-f724-f7ce199c0b36	Martinlaakso
Sujuva Yleismies	1,49078E+12	29.3.2017 10:12	A	2. Työmesta	Ei kerrosta	9d04050a-f434-2a7c-06c8-8a648bb6e3c0	Martinlaakso
Aleksi Eerola	1,49077E+12	29.3.2017 7:13	A	1. Suunnitelmat	Ei kerrosta	dc9ba7dc-ff82-2981-c850-8199dd85e78c	Martinlaakso
Jari matilainena	1,4906E+12	27.3.2017 8:09	A	2. Työmesta	6	f2657304-8550-9fae-9de7-65598f49492d	Martinlaakso
Jari matilainena	1,4906E+12	27.3.2017 7:00	A	3. Työkalut	6	dda01de0-cde2-816d-ca65-c561af85aea9	Martinlaakso
kristo männik	1,4906E+12	27.3.2017 6:59	B	3. Työkalut	6	4cd3cc07-ea7e-1963-3c3c-ee11cee9a6b6	Martinlaakso
Aleksi Eerola	1,4906E+12	27.3.2017 6:59	A	2. Työmesta	7	bb8900cb-d209-fca6-08d5-bc8844ece2f3	Martinlaakso
Rein Rand	1,4906E+12	27.3.2017 6:59	B	2. Työmesta	1	23bcfa8c-642c-b295-b117-ddfbcd07c57a	Martinlaakso
Sami Ilonen	1,4906E+12	27.3.2017 6:59	A	4. Resurssit	Ei kerrosta	92f2e6e2-372c-05ac-a504-607a54569225	Martinlaakso
Tuomo Pikkusilta	1,4906E+12	27.3.2017 6:59	A	2. Työmesta	3	d435ad93-995d-aff9-0237-b0b49d4740b2	Martinlaakso
Sami Ilonen	1,4906E+12	27.3.2017 6:56	B	2. Työmesta	3	71594592-30a1-9566-7583-174d97ba3f3f	Martinlaakso
Tuomo Pikkusilta	1,4906E+12	27.3.2017 6:55	B	2. Työmesta	3	c7e5aefd-090e-5f32-d0fa-4920a05c4856	Martinlaakso
Aleksi Eerola	1,4906E+12	27.3.2017 6:55	B	2. Työmesta	4	6d032377-e779-505e-4eb7-b3c1c634c735	Martinlaakso
Sami Ilonen	1,4906E+12	27.3.2017 6:55	B	2. Työmesta	3	bf655406-1e85-eeac-7e6e-d25bf696bd9f	Martinlaakso
Tuomo Pikkusilta	1,4906E+12	27.3.2017 6:54	C	2. Työmesta	3	ff4eea1b-88b4-c61b-5e7d-de17b92982cf	Martinlaakso
Jari matilainena	1,4906E+12	27.3.2017 6:51	B	2. Työmesta	4	ab915c2f-91ea-5f8b-5772-0661292d1885	Martinlaakso
Rein Rand	1,4906E+12	27.3.2017 6:50	B	2. Työmesta	2	9fb9d7e7-9ea3-00fa-3c03-6a0b9428a169	Martinlaakso
kristo männik	1,4906E+12	27.3.2017 6:50	B	3. Työkalut	6	017e0551-6587-5ab7-8639-ba5cfe1a7703	Martinlaakso

modified (N)	modified (N)	room (S)	status (S)	to_id (S)	urgency (N)	subject (S)
1,49389E+12	4.5.2017 9:33	Ei asuntoa	closed	Sami Ilonen	2	lattialaatat puutuu
1,4938E+12	3.5.2017 8:53	Ei asuntoa	closed	Sami Ilonen	2	tehoste laatat puutuu
1,49181E+12	10.4.2017 7:17	Ei asuntoa	closed	Sami Ilonen	1	kaikki kylpärit on täynä tavaraa
1,49145E+12	6.4.2017 4:35	Irtaimistovarasto 1	closed	Tuomo Pikkusilta	1	kuitulatyian kuidun kohdat paikkaus ennen maalia?
1,49252E+12	18.4.2017 12:00	84	closed	Sami Ilonen	2	kynnys puuttuu edelleen!
1,4913E+12	4.4.2017 11:05	90	texted	Sami Ilonen	2	Hei, haluaisin 3100 tasoite 7 säkki
1,49095E+12	31.3.2017 10:00	58	closed	Sami Ilonen	2	laattoja tiellä
1,4912E+12	3.4.2017 5:42	52	fixing	Jari matilainena	2	mujua lattialla
1,49095E+12	31.3.2017 10:03	Ei asuntoa	closed	Tuomo Pikkusilta	1	Käytävän valo sammuu
1,49129E+12	4.4.2017 8:00	49	fixing	Jari matilainena	1	roilo täyttämättä
1,49094E+12	31.3.2017 7:12	Ei asuntoa	closed	kristo männik	2	laattaroskien siivous
1,49088E+12	30.3.2017 12:27	Ei asuntoa	closed	Sami Ilonen	2	helmalaatat on viety pois
1,49094E+12	31.3.2017 6:26	59	closed	Sami Ilonen	1	testi
1,49086E+12	30.3.2017 6:39	49	closed	Tuomo Pikkusilta	2	muuraus vajaa
1,49086E+12	30.3.2017 6:40	119	closed	Tuomo Pikkusilta	3	Onko meidän jäljiltä? voiko laittaa kiinni?
1,49085E+12	30.3.2017 5:01	84	closed	Sami Ilonen	2	vesieristys kynnys puuttuu
1,49088E+12	30.3.2017 12:01	44	closed	Tuomo Pikkusilta	1	kipsi loppuu 2 säkin jälkeen. kipsi taisi olla lisää varaston edessä?
1,49078E+12	29.3.2017 10:14	Ei asuntoa	closed	Riikka Hurme ncc	1	telakka ei toimi
1,49077E+12	29.3.2017 7:13	Ei asuntoa	closed	Sami Ilonen	2	erillis wc seiniä ei vesieristetä, vain kosteussulku. lattiavedieristet
1,4906E+12	27.3.2017 8:10	34	closed	Tuomo Pikkusilta	3	
1,4906E+12	27.3.2017 7:01	37	closed	Tuomo Pikkusilta	2	
1,4906E+12	27.3.2017 7:00	84	closed	Sami Ilonen	1	Nyt apua
1,4906E+12	27.3.2017 7:00	42	closed	Jari matilainena	1	ok
1,4906E+12	27.3.2017 7:00	53	closed	Sami Ilonen	1	parvekeoven smyygi oikaisematta
1,4906E+12	27.3.2017 7:00	Ei asuntoa	closed	Tuomo Pikkusilta	2	
1,4907E+12	28.3.2017 12:00	11	closed	Jari matilainena	2	lisää rahaa
1,4906E+12	27.3.2017 6:57	62	closed	Rein Rand	2	lisää kahvia
1,4907E+12	28.3.2017 12:01	61	closed	Jari matilainena	2	laattaroskia
1,4906E+12	27.3.2017 6:57	Ei asuntoa	closed	kristo männik	2	siivoa jälkesi
1,4906E+12	27.3.2017 6:57	62	closed	kristo männik	2	kylppäreihi jätetty laattojen leikkuupalat
1,4906E+12	27.3.2017 6:57	103	closed	Jari matilainen	2	laattaroskia
1,4906E+12	27.3.2017 6:52	70	closed	Tuomo Pikkusilta	1	siivooa jälkesi
1,4906E+12	27.3.2017 6:52	55	closed	Sami Ilonen	1	huoneistossa tavaraa etuputsin edessä
1,4906E+12	27.3.2017 6:52	83	closed	Sami Ilonen	1	maalarin kamat kylpärissä
						muu tavarat laitettu paikkalla